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THE LINEAR COMPRESSION OF VARIOUS SINGLE CRYSTALS TO 30,000 kg/cm²

BY P. W. BRIDGMAN

THE SCATTERING OF HIGH VELOCITY NEUTRAL PARTICLES. I.

BY I. AMDUR, C. F. GLICK AND H. PEARLMAN

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Introduction

During the war a number of laboratories were actively engaged in searching for crystals capable of replacing quartz or rochelle salts for various purposes of transmission or reception, and in this search large programs of crystal growing were carried out. Some of the crystals made in this way were large enough to permit measurements of linear compression, and I was fortunate enough to obtain a number for this purpose. The results on these and one other, magnesium, form the subject of this paper. The crystals investigated here were all such that their distortion under hydrostatic pressure is completely determined if the change of linear dimensions is known in three or fewer orthogonal directions. That is, no monoclinic or triclinic crystals were investigated, although a number of these had been grown for piezo-electrical purposes and were available. Neither were any cubic crystals investigated, such not having piezo-electric properties.

Before undertaking the measurements a preliminary investigation of the substance was made in the apparatus[1] for rapid determination of cubic compressibility to 40,000 to find whether there were any polymorphic transitions in the contemplated range, since measurements of linear compressibility in general have no significance when carried through a transition point. Among the available substances several were found with polymorphic transitions below 30,000. In general no attempt was made to measure the linear compressions of these. The data for their volume compressions will be found in the previous paper describing the measurements with the 40,000 apparatus. One of the substances with a transition, $MgSO_4 7H_2O$, was however measured in the low pressure range below its first transition.

Apparatus and Method

The method used in this work was that of the "lever piezometer," in which the change of dimensions of the specimen is magnified with a lever which moves a wire carrying a current over a contact fixed to the apparatus, the amount of motion being determined by potentiometer measurements of the resistance between a contact fixed to the wire and the contact over which it slides. This method has been extensively employed hitherto[2] up to 12,000 kg/cm², and is the most accurate and sensitive method for the determination of the compression of solids used to date. Its use to 30,000 in the present work is new. The particular point in making the measurements over the wider range is the greater accuracy with which it is possible to determine the changes of compressibility with pressure, knowledge of which is important for the theory of the solid state. Eventually it is intended to measure a large number of substances with similar apparatus over this range; such measurements will form a useful supplement to other less accurate measurements over wider ranges. The particular crystals of this paper are well adapted for the first measurements in this range because their compressibilities are so high that certain irregularities which still persist in the apparatus

are without appreciable effect. Measurements by this method and in this range cannot yet be advantageously made on substances as incompressible as iron, but this part of the program must wait for further improvements, which are already well under way.

Because of the emphasis on precision and the higher order terms it is necessary to take greater care with the measurement of pressure than is adequate, for instance, in the measurements to 100,000. It is now necessary to know the deviation of the manganin gauge from linearity. It has already been established[3] that this deviation is so slight that a calibration at two pressure fixed points is sufficient. The gauges were calibrated by the transition of bismuth and the freezing of mercury at room temperature, the data for which are known. The calibration must be made anew for every individual manganin coil, of which two were used in this work.

The lever piezometer had to be specially designed and constructed. It is somewhat smaller than formerly, being required to fit a hole 0.50 instead of 0.62 inches in diameter. Furthermore, a different method of assembly had to be designed so that the insulating plug at the bottom of the cylinder need not be removed for every new setup, the assembly of this plug being much more time consuming in the 30,000 apparatus than with the former 12,000 apparatus. Mr. L. H. Abbot successfully designed an arrangement of spring clips which permitted the piezometer with specimen in place to be inserted as a single unit into the pressure cylinder from the moving plug end, this plug being naturally removed after every release of pressure. Various calibrations have to be made on the piezometer for the magnification of the lever, the resistance of the wire and its pressure coefficient etc. These calibrations were not essentially different from those previously necessary to 12,000 and need not be described further in detail.

Various minor improvements in the technique of handling the 30,000 apparatus have been effected. Some of these, having to do with methods of assembling the insulating plug and the packing ring for it, have already been described in the previous paper[4] giving new results to 100,000. I now have in all three complete equipments for reaching 30,000. These are somewhat individual in the difficulties which they present. The one in which the present measurements were made has perhaps given the most trouble. An especial trouble with this, not shown by the others, although the construction is identical as far as is evident, has been that the moving piston has a strong tendency to seize on the walls of the cylinder, resulting in abnormally high friction and also leak. This difficulty has been overcome by giving a proper hardness to the moving packing rings and by lightly copper plating before every run the steel parts which move over each other. In addition to these difficulties the most disastrous explosion yet experienced with any 30,000 apparatus occurred during this work. In the design used in the early measurements the insulating plug, where it projects from the pressure cylinder, was without external support for a distance of perhaps 5/16 inch on a diameter of 9/16 inch. There was some plastic swelling of this unsupported part, and in the course of the work this part had been refigured several times by removing altogether a few thousandths of an inch from the diameter. The failure consisted in a complete collapse at the maximum pressure of the unsupported protruding part. This failed by shear on an angle much blunter than 45°, releasing the contents of the cylinder, which were completely destroyed. Evidently the plastic flow in the protruding part, which was of Rockwell C hardness 59, had proceeded beyond the limit of tolerance. The new design was made with only half as long a protruding part, and to date no further difficulty has occurred.

The methods of calculation in the following were like those previously used in the lower range, and need not be further described. The results are essentially differential results with respect to American Ingot iron, the absolute compressibility of which has already been established[5] over this range by a different method. By making calibrating runs with iron, taking the difference between the calibrating run and the actual run and using in the calculation the known absolute value for iron, the absolute changes of dimension in the various crystallographically independent directions could be eventually obtained and tabulated. From the linear changes of dimensions the change of volume was then calculated. In this calculation five place logarithms had to be used, four places being sufficient for the linear changes. Finally, the relative lengths and volumes were calculated from the changes, and recorded in the tables given here.

In the following a rough measure is given of the order of accuracy by recording the average deviation of a single experimental point from a

smooth curve in terms of the percentage of the differential change of dimensions at the highest pressure. The calculations involved first determining at every pressure what the displacement would have been if the relation with pressure had been linear passing through the top point, then plotting the deviation from linearity as a function of pressure, and finally passing a smooth curve through the deviation points. The sum of the deviations from this smooth curve of all the points was obtained by addition with the dividers, and this sum was divided by the total number of observations and the displacement at the maximum to get the average percentage deviation above. In the usual routine, 17 readings uniformly scattered over the entire range were made in addition to an initial seasoning application of 10,000. The 17 readings were made with increasing and decreasing pressure, the decreasing readings being staggered between the increasing readings. The "probable" error of the result tabulated is of course much less than the irregularity of a single reading, perhaps something of the order of one quarter of it for a total of 17 readings, neglecting any systematic error. Furthermore, this error is on the differential compressibility; the absolute compressibility is more accurate by an amount depending on the difference between the substance in question and iron.

Detailed Data

The detailed presentation of data now follows. The substances are given first for which measurements in two directions were sufficient and then those which demanded three. In each section the order is, with two exceptions, the order of increasing volume compression at 30,000. The results are given in tables, length and volume at 2,500, 5,000, and then at 5,000 intervals to 30,000. No attempt has been made to find a universal formula which would cover all the data. A second degree expression such as was usually adequate in the former range up to 12,000 is definitely not adequate in most of the cases, although frequently the failure is by a small amount. Most of the substances in the following are conventional enough in their behavior. Only two have markedly unusual features: $NiSO_46H_2O$, which has a very marked transition of the second kind in one direction, and benzil, which has a more complicated anomaly.

Magnesium. This metal is included here with other dissimilar substances because its absolute compressibility is high enough to permit acceptable measurements with the present apparatus. The material was from the same crystal as that previously measured[6] to 12,000. The results are given in Table I. For the parallel direction the mean deviation of a single reading from a smooth curve was 0.17 per cent, and for the perpendicular direction 0.22 per cent. Compared with previous results the changes of length at 10,000 found now are about 3 per cent less than those formerly found. The curvature or deviation from linearity in the parallel direction is not greatly different from that found before. The curvature in the perpendicular direction, on the other hand, is now materially less than before. The curvature previously found in the perpendicular direction was 50 per cent greater than that in the parallel direction, whereas now the two curvatures are equal within 1 per cent. The compressions in the two directions now found are very nearly equal, as would be expected from the crystal structure of magnesium, a hexagonal close packed structure of *spheres*. The compression found now is about 0.5 per cent greater in the direction parallel to the hexagonal axis than at right angles.

TABLE I

Magnesium

Pressure kg/cm²	Length		Volume
	⊥ hex. axis	|| hex. axis	
0	1.00000	1.00000	1.00000
2,500	.99775	.99770	.99320
5,000	.99553	.99542	.98657
10,000	.99122	.99100	.97366
15,000	.98716	.98683	.96166
20,000	.98322	.98280	.95010
25,000	.97954	.97904	.93938
30,000	.97612	.97548	.92944

Ammonium Dihydrogen Phosphate ("*A.D.P.*"). This I owe to the kindness of Dr. Hans Jaffe of the Brush Development Co., the results are shown in Table II. It will be noticed that the

TABLE II

Ammonium Dihydrogen Phosphate

Pressure kg/cm²	Length		Volume
	|| optic axis	⊥ optic axis	
0	1.00000	1.00000	1.00000
2,500	.99542	.99795	.99135
5,000	.99104	.99604	.98322
10,000	.98267	.99253	.96405
15,000	.97511	.98944	.95462
20,000	.96818	.98663	.94247
25,000	.96170	.98389	.93097
30,000	.95557	.98142	.92042

compression is somewhat twice as great parallel to the optic axis as at right angles. The mean deviations of single readings from smooth curves were 0.12 per cent for the parallel direction and 0.65 per cent perpendicular. The greater irregularity perpendicular to the axis corresponds to the smaller compressibility.

Primary Potassium Phosphate ("*P.K.*"). The material was furnished by Dr. Jaffe.

The results are shown in Table III. In the

TABLE III

PRIMARY POTASSIUM PHOSPHATE

Pressure kg/cm²	Length		Volume
	"*a*" direction	"*c*" direction	
0	1.00000	1.00000	1.00000
2,500	.99688	.99734	.99112
5,000	.99405	.99475	.98295
10,000	.98896	.98976	.96802
15,000	.98440	.98487	.95438
20,000	.98018	.98033	.94182
25,000	.97649	.97604	.93068
30,000	.97291	.97212	.92015

"*a*" direction the average deviation of a single reading from a smooth curve was 0.41 per cent, and in the "*c*" direction 0.47 per cent. Compared with ammonium dihydrogen phosphate the overall cubic compression is very nearly the same, but the linear compression does not follow the same pattern, being very nearly the same for the two directions for P.K., whereas there was a difference by a factor of two for A.D.P. There seem to be no previous measurements on either of these materials for comparison.

$LiNa_3Cr_2O_7 6H_2O$. This material I owe to the kindness of Dr. S. O. Morgan of the Bell Telephone Laboratories.

The results are shown in Table IV. The com-

TABLE IV

$LiNa_3Cr_2O_7 6H_2O$

Pressure kg/cm²	Length		Volume
	x direction	*z* direction	
0	1.00000	1.00000	1.00000
2,500	.99696	.99698	.99095
5,000	.99400	.99446	.98256
10,000	.98832	.98975	.96676
15,000	.98300	.98540	.95216
20,000	.97804	.98144	.93882
25,000	.97315	.97786	.92604
30,000	.96849	.97446	.91400

pression in the *z* direction is about 20 per cent less than at right angles. The mean deviation of a single reading from a smooth curve was 0.18 per cent for the *x* direction, and 0.25 per cent for *z*. There are no previously published measurements for comparison. The 40,000 apparatus gave for the volume decrement at 30,000 0.0885 against 0.0860 calculated above.

Rubidium Tartrate. The material was supplied by Dr. Morgan.

The results are given in Table V. The com-

TABLE V

RUBIDIUM TARTRATE

Pressure kg/cm²	Length		Volume
	x direction	*z* direction	
0	1.00000	1.00000	1.00000
2,500	.99569	.99821	.98965
5,000	.99151	.99671	.97985
10,000	.98362	.99389	.96162
15,000	.97656	.99144	.94552
20,000	.96992	.98949	.93090
25,000	.96390	.98776	.91772
30,000	.95858	.98625	.90624

pressibility in the *z* direction is only one third as great as at right angles. The mean deviation of a single reading from a smooth curve was 0.25 per cent for the *x* direction, and 0.6 per cent for *z*. The only previous measurements for comparison are those of the volume decrement with the 40,000 apparatus. This apparatus gave for the volume decrement at 30,000 0.1014, against 0.0938 above from the linear compressions. The discrepancy is larger than usual.

Dextrose Sodium Chloride. The material was supplied by Dr. Morgan.

The results are given in Table VI. The com-

TABLE VI

DEXTROSE SODIUM CHLORIDE

Pressure kg/cm²	Length		Volume
	x direction	*z* direction	
0	1.00000	1.00000	1.00000
2,500	.99494	.99714	.98710
5,000	.98972	.99445	.97410
10,000	.98028	.98911	.95048
15,000	.97339	.98427	.93260
20,000	.96648	.98000	.91540
25,000	.96037	.97557	.89974
30,000	.95443	.97172	.88516

pressibility in the *z* direction is roughly one half that at right angles. In the *z* direction there is an abnormal episode between 17,000 and 25,000, the compressibility dropping with pressure at an abnormally high rate at the beginning of the interval. Since all the experimental points consistently indicated the same thing it seems

probable that the abnormality is real, and it was therefore not smoothed out in the table. This abnormality does not seem to fall under the conventional classifications as transition of the second or higher order.

The mean deviation of a single reading from a smooth curve was 0.73 per cent in the x direction and 0.26 in z. The only previous measurements for comparison are with the 40,000 apparatus. This gave for the volume decrement at 30,000 0.1178 against 0.1148 above.

Dextrose Sodium Iodide. The material was furnished by Dr. Morgan.

The results are given in Table VII. The

TABLE VII

DEXTROSE SODIUM IODIDE

Pressure kg/cm²	Length		Volume
	x direction	z direction	
0	1.00000	1.00000	1.00000
2,500	.99478	.99612	.98576
5,000	.99008	.99240	.97282
10,000	.98172	.98532	.94964
15,000	.97434	.97865	.92907
20,000	.96791	.97293	.91146
25,000	.96194	.96767	.89544
30,000	.95692	.96286	.88166

average deviation of a single reading from a smooth curve was 0.08 per cent for the x direction and 0.24 for z. The volume decrement given by the 40,000 apparatus at 30,000 was 0.1196 against 0.1183 above. It is to be noticed that the compressibilities in the two directions are much more nearly equal for dextrose sodium iodide than they are for the corresponding chloride. The volume decrement of the iodide is greater by a small amount. A difference in this direction would be expected on general grounds as a result of replacing chlorine with iodine.

$NiSO_46H_2O$. This was supplied by Dr. Morgan.

The behavior in the z direction up to 30,000 proved to be entirely normal. In the direction at right angles, however, there is a very marked anomaly in the neighborhood of 20,000, as shown in Figure 1. Below 20,000 the length decreases nearly linearly with pressure with a mean compressibility only about 40 per cent of that in the z direction. Near 20,000 there is a very rapid increase of compressibility in a narrow pressure interval, the maximum compressibility attained being approximately 20 fold the original. Between 20,000 and 30,000 the relation between length in the x direction and pressure is very far

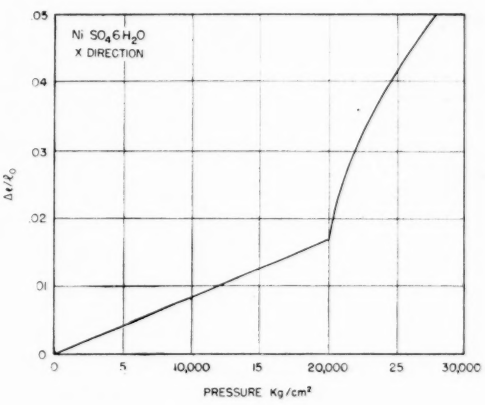

FIGURE 1. The relative change of length perpendicular to the axis of $NiSO_46H_2O$ as a function of pressure.

from linear, the compressibility at 30,000 having dropped to approximately one third that at 20,000.

Four different set-ups with four different specimens were made in the x direction. Two of the specimens were cut at right angles to each other, both in the plane perpendicular to z, in order to check whether any triaxiality developed above the transition point. No evidence for this was found. The behavior of these four samples differed slightly and beyond the errors of measurement. The pressure of discontinuity was 19,320, 19,700, 20,000 and 20,050 for the four specimens respectively. The maximum difference in the changes of length was about 2 per cent. The results given in the table are a rough average for the four directions, taking the pressure of discontinuity as 20,000 and throwing the most weight above the transition on the one specimen which was taken up to the full 30,000.

If pressure readings are taken close together in the region of the anomaly the sharp discontinuity disappears, and there appears only a region of very rapidly varying curvature. In Figure 2 the fine detail is shown in the neighborhood of the anomaly. The points in this diagram were taken with decreasing pressure after the full 30,000 had been reached. This excursion to the maximum produced an irreversible permanent fractional change of length when 20,000 was recovered of 0.0004.

The final results, with the fine detail in the region of anomaly smoothed over, are shown in Table VIII. In the z direction the average

TABLE VIII

$NiSO_4 6H_2O$

Pressure kg/cm²	Length		Volume
	x direction	z direction	
0	1.00000	1.00000	1.00000
2,500	.99828	.99491	.99148
5,000	.99661	.99014	.98345
10,000	.99331	.98104	.96796
15,000	.99005	.97291	.95365
20,000	.98685	.96575	.94050
22,500	.97216	.96263	.90978
25,000	.96284	.95991	.88990
27,500	.95653	.95738	.87594
30,000	.95122	.95511	.86420

deviation of a single reading from a smooth curve was 0.15 per cent, and in the perpendicular direction (best of the four runs and below the anomaly) was 0.46 per cent.

As usual, the preliminary examination was made in the 40,000 apparatus, and an accelerated increase of compressibility found in the neighborhood of 20,000. However, this had none of the abruptness of the change of linear dimensions. The change of volume at 30,000 given by the 40,000 apparatus was 0.0870 against 0.1358 above. The magnitude of the discrepancy is quite without precedent, and is impossible to explain by error. The effect must be real, and it must mean that whatever it is that occurs at 20,000 is to a great extent suppressed under the constraints imposed in the 40,000 apparatus, in which pressure fails to be hydrostatic by several hundred kilograms under the best conditions, and by much more under unfavorable conditions of high rigidity in the specimen and large difference of compressibility in different directions. The lat-

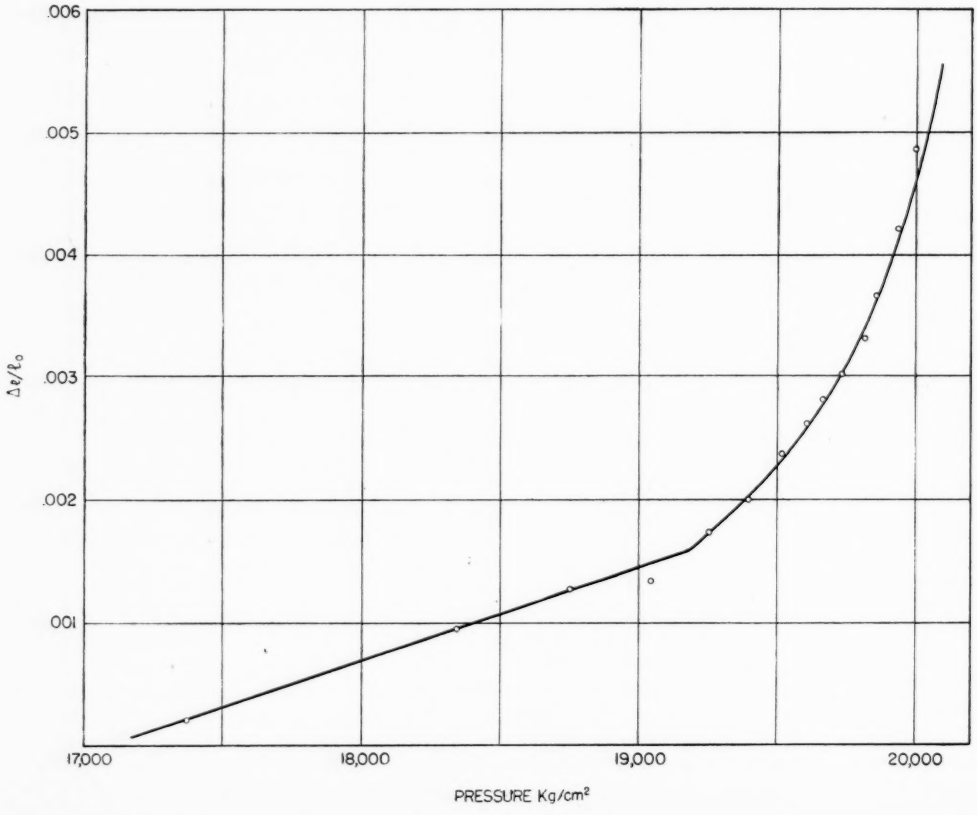

FIGURE 2. Plot on a much enlarged scale of the neighborhond of the break in Figure 1. together with the experimental points obtained with decreasing pressure.

ter condition, at least, is fulfilled by the present substance.

Benzil. I owe this to the kind offices of Lt. Paul H. Egli, through whom the Naval Research Laboratory supplied it to me. The orientations were kindly identified by Professor C. Frondel of the Department of Mineralogy of Harvard University.

Both directions are anomalous, and furthermore the anomalies are not connected in the way demanded by thermodynamics if the stress system is a pure hydrostatic pressure. The explanation does not appear, but must be connected in some way with a slight failure of the stress to be hydrostatic. The specimen in the piezometer, in order to be sure that all contacts shall be tight and there shall be no back lash, is subjected to a unidirectional compressional stress along the axis in addition to the hydrostatic pressure. This stress is of the order of only 0.5 kg/cm². Never before has there been any evidence that this stress plays any role.

Two specimens were used in each direction, and the anomalies repeated. The mean deviation of a single point from a smooth curve was 0.24 per cent for the "*a*" direction and 0.25 per cent for "*c*". The anomaly in the *c* direction consists in an abrupt *increase* of length at 22,500. From here the curve follows along parallel to its course before the jump, but on a higher level, until 26,800, when there is an abrupt downward turn in direction, but no discontinuity, until at 28,500 a rough prolongation of the original curve is reached. Pressure was not carried beyond this point. On release of pressure the course with increase of pressure was reversibly retraced. The experimental points are shown in Figure 3. Thermodynamics, of course, permits only transitions with decrease of volume, so that in the "*a*" direction this anomaly would demand a discontinuous decrease of length large enough to at least compensate for the increase at right angles. However, no anomaly whatever was found in the "*a*" direction at 22,500. There is a smaller repeatable and reversible anomaly at 12,500, which consists in a cusp-like increase of compressibility, or at least cusp-like to pressure readings spaced about 2,000 kg/cm² apart. This is followed by an inverse anomaly at 25,000, the compressibility becoming discontinuously smaller. This latter anomaly was reversible, but it was not checked by repetition with the second specimen, which was made so long in order to give greater

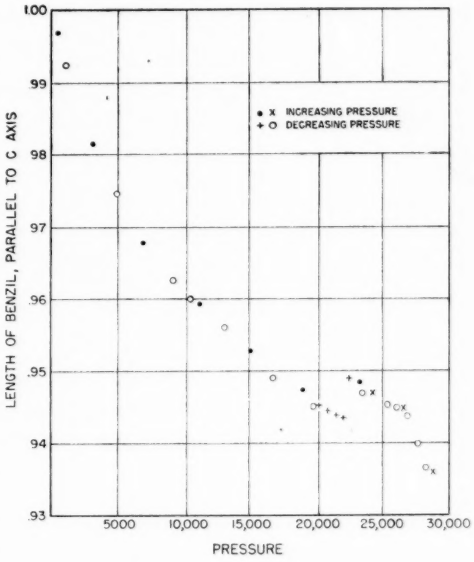

FIGURE 3. The relative change of length perpendicular to the axis of benzil as a function of pressure. The increase of length between 20,000 and 25,000 is reversible.

sensitiveness that it could not be carried above 25,000 without running beyond the stroke of the lever.

These anomalies are reproduced as they were found in Table IX. It would be misleading to calculate from the changes of length the volume change, and this column is therefore omitted.

TABLE IX

BENZIL

Pressure kg/cm²	Length	
	a direction	*c* direction
0	1.0000	1.0000
2,500	.9905	.9832
5,000	.9833	.9731
7,500	.9766	
10,000	.9705	.9598
12,500	.9650	
15,000	.9569	.9513
17,500	.9500	
20,000	.9438	.9446
23,500	.9379	.9418
		.9470
25,000	.9321	.9440
26,800		.9423
27,500	.9299	
28,500		.9345
30,000	.9269	

Preliminary measurements were made as usual

in the 40,000 apparatus, and no anomalies found at all. The change of volume at 30,000 found with it was 0.184, which is not far from what would be computed by taking the changes of length in Table IX at their face value.

Sodium Ammonium Tartrate. The material was furnished by Dr. Morgan.

The measurements went smoothly and without episode. Two complete sets of measurements were made on this substance with six specimens in all. The repetition was made necessary by a confusion of orientations in the first set by which two "y" orientations were measured and no x. On the repetition the agreement in the changes of length was exact for the y orientation and within 1 per cent for z. The results shown in Table X are those of the second set. The mean

TABLE X

SODIUM AMMONIUM TARTRATE

Pressure kg/cm²	Length			Volume
	x direction	y direction	z direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99332	.99752	.99622	.98712
5,000	.98693	.99523	.99263	.97498
10,000	.97556	.99108	.98612	.95342
15,000	.96575	.98739	.97994	.93444
20,000	.95701	.98403	.97468	.91788
25,000	.94907	.98082	.96993	.90288
30,000	.94284	.97784	.96564	.89028

deviations of single readings from smooth curves for the x, y, and z directions respectively were: 0.23, 0.43, and 0.27 per cent. The volume decrement at 30,000 obtained with the 40,000 apparatus was 0.1148 against 0.1097 above.

Strontium Formate. The material was supplied by the Naval Research Laboratory, and the identification of orientations made by Professor Frondel.

The results are shown in Table XI. The average deviations of single readings from smooth

TABLE XI

STRONTIUM FORMATE

Pressure kg/cm²	Length			Volume
	a direction	b direction	c direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99670	.99802	.99617	.99092
5,000	.99390	.99610	.99271	.98278
10,000	.98870	.99236	.98629	.96770
15,000	.98387	.98886	.98024	.95368
20,000	.97932	.98566	.97452	.94068
25,000	.97516	.98260	.96923	.92870
30,000	.97143	.97965	.96426	.91764

curves in the a, b, and c directions were 0.42, 1.5, and 0.33 per cent respectively. The volume decrement at 30,000 found with the 40,000 apparatus was 0.0858 against 0.0824 above.

Sulfamic Acid. The material was supplied by Dr. Jaffe, who identified the axis. The system of axes adopted is that of Jaeger as quoted by Bryant.[7] "According to this system the b axis coincides with the acute bisectrix. The c axis coincides with the normal to the optic plane."

TABLE XII

SULFAMIC ACID

Pressure kg/cm²	Length			Volume
	a direction	b direction	c direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99698	.99682	.99592	.98978
5,000	.99433	.99402	.99195	.98046
10,000	.98948	.98898	.98495	.96385
15,000	.98513	.98432	.97863	.94896
20,000	.98114	.98007	.97295	.93558
25,000	.97748	.97633	.96827	.92406
30,000	.97419	.97306	.96386	.91370

The results are shown in Table XII. The average deviations of single readings from smooth curves in the a, b, and c directions were 0.42, 0.36, and 0.36 per cent respectively. The volume decrement at 30,000 found with the 40,000 apparatus was 0.0885 against 0.0863 above.

HIO_3. The material was supplied by the Naval Research Laboratory and the identification of directions made by Professor Frondel.

TABLE XIII

HIO_3

Pressure kg/cm²	Length			Volume
	a direction	b direction	c direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99789	.99481	.99625	.98900
5,000	.99592	.98995	.99276	.97880
10,000	.99229	.98106	.98688	.96070
15,000	.98894	.97349	.98034	.94382
20,000	.98588	.96680	.97510	.92942
25,000	.98316	.96059	.97020	.91534
30,000	.98068	.95549	.96560	.90482

The results are shown in Table XIII. The average deviations of single readings from smooth curves in the a, b, and c directions were 0.62, 0.24, and 0.62 per cent respectively. The volume decrement at 30,000 obtained with the 40,000 apparatus was 0.1015 against 0.0952 above.

$MgSO_47H_2O$. This material I owe to the kindness of Mr. George C. Kennedey, who grew the crystals especially for these measurements from

aqueous solution by the method of slowly lowering the temperature. The work was done at Harvard University. During the war Mr. Kennedey had been engaged on similar work for the Navy.

Preliminary exploration with the 40,000 apparatus disclosed three transitions, one between 10,000 and 15,000, and two close together and not completely resolved in the neighborhood of 25,000. All these transitions are sluggish, with a wide region of indifference. The present measurements were of necessity restricted to pressures below 10,000. Even in this range the results were more irregular than usual.

TABLE XIV

$MgSO_4 7H_2O$

Pressure kg/cm²	Length			Volume
	a direction	*b* direction	*c* direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99666	.99563	.99649	.98880
5,000	.99348	.99131	.99341	.97834
7,500	.99042	.98705	.99070	.96850
10,000	.98750	.98286	.98826	.95918

The results are shown in Table XIV. The average deviation of a single reading from a smooth curve was 1.1, 0.75, and 1.2 per cent respectively for the *a*, *b*, and *c* directions. The change of volume at 10,000 found with the 40,000 apparatus was 0.0445 against 0.0408 above. The discrepancy is largely due to uncertainty in the 40,000 measurements due to sluggishness of the transitions.

Morpholine Hydrogen Tartrate. The material was supplied by Dr. Morgan.

TABLE XV

Morpholine Hydrogen Tartrate

Pressure kg/cm²	Length			Volume
	x direction	*y* direction	*z* direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99191	.99786	.99346	.98324
5,000	.98521	.99585	.98378	.96516
10,000	.97345	.99203	.97202	.93866
15,000	.96402	.98856	.96289	.91764
20,000	.95573	.98532	.95555	.89982
25,000	.94850	.98229	.94888	.88408
30,000	.94191	.97954	.94384	.87080

The results are shown in Table XV. The mean deviation of a single reading from a smooth curve for the *x*, *y*, and *z*, directions respectively was 0.10, 0.46 and 0.15 per cent. The voulme decrement at 30,000 found with the 40,000 apparatus was 0.1228 against 0.1292 above. The measurements with this material went smoothly in all respects with a minimum of the irregularities which some of the other materials show. I think that many of these irregularities are not instrumental, but are genuinely associated with the materials.

Rochelle Salts. The material was supplied by Dr. Jaffe. Two completely independent sets of measurements were made with material from two different crystals. On the first determination there was apparently a confusion with regard to the "*b*" orientation, this apparently having been replaced by the *a* orientation. Repetition of the results was therefore demanded. Dr. Jaffe kindly provided a second batch of material with orientations marked, and Professor Frondel made an independent confirmation of the orientations.

TABLE XVI

Rochelle Salts

Pressure kg/cm²	Length			Volume
	a direction	*b* direction	*c* direction	
0	1.00000	1.00000	1.00000	1.00000
2,500	.99382	.99743	.99613	.98742
5,000	.98789	.99505	.99260	.97570
10,000	.97773	.99043	.98626	.95504
15,000	.96868	.98628	.98079	.93704
20,000	.96032	.98270	.97588	.92096
25,000	.95270	.97975	.97151	.90684
30,000	.94597	.97722	.96728	.89420

The results for the second specimen are shown in Table XVI. The decrements of length in the *a* and *c* directions given by the first specimen agreed within about one per cent with the corresponding values for the second. The mean deviations of a single reading from a smooth curve for the *a*, *b*, and *c*, directions were respectively 0.28, 1,23, and 0.42 per cent respectively.

The confirmation of the results in Table XVI by the volume decrements measured independently with the 40,000 apparatus was closer than usual. The volume decrement at 30,000 given by the latter was 0.1053 against 0.1058 of the table. In addition to this, comparison may be made with my own former measurements[8] of the change of length up to 12,000 kg/cm². The decrements of length at 10,000 kg/cm² formerly found in the *a*, *b*, and *c* directions respectively were 0.01029, 0.02217, and 0.01320 against 0.02227, 0.00957, and 0.01374 now given in Table XVI. It would appear that *a* and *b* orientations in the former work must have been

inverted, a probability which is strengthened by inspection of the original note books.

There seem to be no other measurements under hydrostatic pressure for comparison. There have, however, been a number of measurements of the elastic constants at atmospheric pressure from which the initial compressibilities may be computed. A summary of these may be found in Cady's book on Piezoelectricity. It would appear from an inspection of this work that none of the measurements of elastic constants are accurate enough to allow computations of the linear compressibilities of any reliability. In this calculation the errors conspire in a particularly unfavorable way. For instance, the linear compressibility in the b direction calculated with that combination of constants which is recommended as best turns out to be negative, a conclusion which can be rejected with confidence on the basis of the direct measurements. In general, the error in measuring the linear compressibilities appears to be much less than that in measuring the other constants, so that in calculating the other constants adjustments should be made so that they will yield the measured linear compressibilities.

Discussion

This discussion will be concerned with several purely formal matters with the object of giving a better descriptive grasp of the results, and will not attempt at all to assess their physical significance.

In the first place, the magnitude of the mean compression is of interest. As a measure of this we may take the volume decrement under 30,000. Omitting the only metal in the above list, magnesium, and confining attention to the salts, the smallest volume decrement is for Ammonium Dihydrogen Phosphate, 0.0796, and the largest for $NiSO_46H_2O$, 0.1358. This is variation by less than a factor of two, which is comparatively small in view of the known variation by a factor of 300 between the least and most compressible elements, carbon and caesium. In speculating on the reason for this it is to be remembered that all the substances measured here have this in common, that they are soluble in water and were grown in single crystal form from aqueous solution.

The degree of anisotropy of the crystal with regard to hydrostatic compression is of interest. This may be arbitrarily defined as the ratio of the decrement of linear dimension in the direction in which it is greatest to that in the direction in

TABLE XVII

Summary

Substance	∥ axis, c, or z			⊥ axis, a, or x			⊥ axis, b, or y			Volume			Anisotropy	
	$\left(\frac{\Delta l}{l_0}\right)_{30,000}$	Deviation	Relative Deviation	$\left(\frac{\Delta l}{l_0}\right)_{30,000}$	Deviation	Relative Deviation	$\left(\frac{\Delta l}{l_0}\right)_{30,000}$	Deviation	Relative Deviation	$\left(\frac{\Delta V}{V_0}\right)_{30,000}$	Deviation	Relative Deviation	Magnitude	Axes of greatest and least compression
Magnesium	.02452	.0370	1.51	.02388	.0377	1.58				.07056	.0435	0.62	1.026	c, a
Ammonium Dihydrogen Phosphate	.04443	.0603	1.36	.01858	.0684	3.68				.07958	.0702	0.88	2.39	c, a
Primary Potassium Phosphate	.02788	.0427	1.53	.02709	.0761	2.81				.07985	.0714	0.89	1.027	c, a
$LiNa_5Cr_2O_7 6H_2O$	.02554	.0717	2.80	.03151	.0397	1.26				.08600	.0563	0.65	1.234	a, c
Rubidium Tartrate	.01375	.1084	7.89	.04142	.0659	1.59				.09376	.0811	0.86	3.01	a, c
Dextrose Sodium Chloride	.02828	.0562	1.99	.04557	.0840	1.84				.11484	.0867	0.76	1.61	a, c
Dextrose Sodium Iodide	.03714	.0748	2.01	.04308	.0957	2.22				.11834	.0993	0.84	1.163	a, c
$NiSO_46H_2O$	.04489	.1035	2.30	.04878	−.296	−6.07				.13580	−.159	−1.17	1.086	a, c
Sodium Ammonium Tartrate	.03436	.0837	2.43	.05716	.0992	1.73	.02216	.0689	3.12	.10972	.0977	0.89	2.58	a, b
Strontium Formate	.03574	.0528	1.48	.02857	.0648	2.27	.02035	.0478	2.35	.08236	.0624	0.76	1.755	c, b
Sulfamic Acid	.03614	.0913	2.52	.02581	.0763	2.95	.02694	.0822	3.05	.08630	.0914	1.06	1.40	c, a
HIO_3	.03440	.0716	2.08	.01932	.0725	3.75	.04451	.0958	2.15	.09518	.0902	0.95	2.30	b, a
Morpholine Hydrogen Tartrate	.05616	.1606	2.85	.05809	.1193	2.05	.02046	.0592	2.89	.12920	.1374	1.06	2.84	a, b
Rochelle Salts	.03272	.0865	2.64	.05403	.0797	1.47	.02278	.1024	4.50	.10580	.0998	0.94	2.37	a, b

which it is least. This is shown in Table XVII. Among the crystals with rotational symmetry requiring two constants, three are more compressible along the axis, and four at right angles. The anisotropy varies from 3.01 for rubidium tartrate to 1.029 for Primary Potassium Phosphate and 1.026 for magnesium. Among the orthorhombic crystals requiring three constants three are most compressible along the c axis, two along a and one along b. The anisotropy in this group varies from 2.84 for morpholine hydrogen tartrate to 1.398 for sulfamic acid. The anisotropy shown by this group of crystals is not large when it is considered that zinc is eight times more compressible along the axis than at right angles, and tellurium has a negative ratio in the two directions.

We next consider the deviations from linearity, or the curvature in the relation between pressure and distortion. This may be arbitrarily defined as the ratio of the difference between the actual distortion at 15,000 and the distortion which would have occurred at 15,000 if the relation were linear up to 30,000, to the distortion at 30,000. Expressed analytically for change of length, this is:

$$\text{Deviation} = \frac{\Delta l_{15,000} - \tfrac{1}{2}\Delta l_{30,0000}}{\Delta l_{30,000}}$$

Previous experience would lead to the expectation that the "deviation" so defined would be larger the larger the absolute value of the distortion, or that deviation divided by the decrement of length at 30,000 would be roughly of the order of magnitude of unity and would not vary greatly from substance to substance. I have already shown that when the volume change up to 12,000 kg/cm^2 is represented by the two constant formula $\Delta V/V_0 = -ap + bp^2$, the dimensionless combination b/a^2 varies in the general neighborhood of unity.

In Table XVII are given the changes of dimensions at 30,000, the deviations, and the ratio of the deviation to the change at 30,000. This latter we may define as the "relative deviation." The deviation varies from a maximum of 0.161 for morpholine hydrogen tartrate to a minimum among the salts of 0.0397 for $LiNa_3Cr_2O_76H_2O$ and 0.0372 for magnesium. No correlation is obvious between deviation and direction in the crystal. The relative deviation, omitting for the moment rubidium tartrate, varies from 3.75 to 1.36 for changes of length and from 1.06 to 0.616 for changes of volume. The expectation is borne out that the relative deviation fluctuates in the general neighborhood of unity. Its range of fluctuation is definitely less than the range of fluctuation of the deviation itself, but the difference is not overwhelming. The deviation for the volume is in general not far from the deviation for the length, which means that the relative deviation for the volume is of the order of one third the relative deviation for length. There seems no general correlation between the relative deviation and direction.

Rubidium Tartrate is clearly an exception. Along the axis the compressibility is by far the least of any substance in the table, whereas at the same time its deviation from linearity is among the highest and its relative deviation is entirely out of line, being 7.89 against a next nearest figure 3.75. One might be tempted to suspect an approach to a transition of the second kind, but as a matter of fact the abnormally high curvature is distributed uniformly over the whole pressure range.

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THE SCATTERING OF HIGH VELOCITY NEUTRAL PARTICLES. I.

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(Contribution from the Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts)

THE SCATTERING OF HIGH VELOCITY NEUTRAL PARTICLES. I.

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A. INTRODUCTION

The estimation of the interaction energies between atoms and molecules as functions of their separation distances is of fundamental importance for a complete understanding of numerous chemical and physical problems. Among the many properties which can be calculated from theory if the mutual energy of interaction is known are: compressibility and thermal expansion of solids and liquids, and transport properties (viscosity, thermal conductivity, and diffusion coefficients) of gases. To date, much of the information on intermolecular interactions has been derived from experimental measurements of these properties and their temperature coefficients. The results have not been completely satisfactory, however, for several reasons. First, the existence of intermolecular forces results, in some cases, in producing perturbations of the properties of an ideal system of forceless molecules, as, for example, the pressure-volume-temperature relations of a mass of a gas. When this perturbation is not very large, it is very difficult to estimate interaction potentials from experimental measurements with satisfactory accuracy. Second, the theoretical treatment of the experimentally measured property is often so complicated that drastic simplification of the molecular model must be made before it is possible to obtain numerical values for the interaction potential. As a result, the conclusions often bear little resemblance to reality, as in the case of molecular models of mass points possessing only repulsive forces which are frequently assumed in order to deduce interaction potentials from experimental values of the coefficients of viscosity, thermal conductivity, and diffusion of gases at relatively low temperatures. Finally, the limited temperature range over which it is possible to make measurements results, in many cases, in values of the mutual potential energy which are valid over very narrow ranges of the separation distance.

A more direct approach to the experimental determination of intermolecular interactions would seem to lie in attempts to study actual collisions between molecules. If the masses, initial speeds, final speeds, and direction of scattering are known for a colliding system, it is possible to determine the potential energy of interaction at the distance of closest approach of the two particles.[1] This method of attack has the advantage that the effects of molecular interactions are not reflected in small changes in compressibility, viscosity, or similar properties characteristic of large aggregates of molecules, but directly in the change in speed and direction of the interacting molecules. As a consequence, the results of scattering experiments tend to lead directly to the desired information about molecular interactions. However, the experimental difficulties are great since well defined, unidirec-

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[1] E. H. Kennard, *Kinetic Theory of Gases* (McGraw-Hill Book Company, Inc., New York, 1938), pp. 115–134.

tional beams of collision free neutral particles and accurate methods for detecting such beams are required. The discovery of Dunoyer[2] that thermal velocity molecular beams could be produced by methods similar to those used in collimating light showed that an experimental study of the physical characteristics of single collisions was plausible. The techniques of the molecular beam method were brilliantly developed by Stern and his co-workers[3] between 1923 and 1933 so that the thermal velocity beam is now a well established, accurate research tool.

The scattering of molecular beams with ordinary thermal velocities provides information concerning intermolecular forces at relatively large separation distances where forces of attraction usually predominate over forces of repulsion.[4] Scattering experiments of this type are of secondary interest to the authors for two reasons. First, other types of measurements already mentioned, although less satisfactory, are capable of supplying information in the same general range of interaction distances. Second, quantum theory calculations have been reasonably successful in predicting the magnitude of attractive forces, particularly for non-polar molecules. On the other hand, at small separation distances where repulsive forces predominate, theoretical calculations are not generally successful or possible and laboratory experiments on large aggregates of molecules are not feasible since temperatures are required in excess of the limit obtainable. Since the scattering of neutral particles with controlled high velocities appears to offer a unique approach to the study of repulsive interaction forces at small distances, the authors have endeavored to develop apparatus and techniques of the same high quality as those used in ordinary thermal velocity beam research.

B. Previous Contributions

Beams of fast neutral atoms were first produced by Oliphant,[5] who found a beam of neutral, metastable ^3S helium atoms while studying beams of helium ions. Beeck[6] produced a beam of fast argon atoms by the process of "umladung" which involves the collision of an accelerated ion with a slow atom and results in a transfer of kinetic energy to yield a fast neutral atom and a slow ion. This method was further investigated by Kallman and his co-workers,[7] and later used by Rostagni[8] to produce beams of fast hydrogen, argon and neon.

Amdur and Pearlman,[9] using a device similar to the proton source of Lamar and Luhr,[10] introduced the use of high velocity neutral beams for the determination of repulsive intermolecular potentials from measured total collision cross-sections. They scattered fast hydrogen atoms in room temperature hydrogen gas and fast helium atoms in room temperature helium gas and were able to evaluate interaction potentials from their results. For the system, H—H_2[11], the repulsive potential energy may be expressed as

$$V(r) = 0.846 \times 10^{-10} \exp(-24.9r^2) + 0.211 \times 10^{-10} \exp(-2.40r^2) \text{ erg} \quad (1)$$

for values of r, the distance between mass points representing the hydrogen atom and the hydrogen molecule, in the range 0.28–0.70A. The corresponding relation for the system He—He'[12] is

$$V(r) = 11.3 \times 10^{-10} \exp(-4.63r^{\frac{1}{2}}) \text{ erg} \quad (2)$$

for values of r in the range 0.55–1.05A.

C. Present Contribution

The original apparatus of Amdur and Pearlman had several limitations which restricted the scope of the experiments which could be performed. First, the detector was stationary in the beam axis so that it was not possible to measure the angular distribution of scattering, but only total collision cross-sections. Under such conditions, only one point on the potential energy curve can be obtained from a cross-section value at a given

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beam velocity, in contrast to a series of points derivable from angular intensity measurements of a scattered beam at the same velocity. Second, the long scattering path, about 8.5 cm., introduced uncertainties in the estimation of the angular aperture subtended by the detector which were reflected in the final potential energy relations. Finally, it was necessary to make relatively large corrections to the observed scattered beam intensities because of the large pressure dependence of the detector which was not isolated from the scattering gas. It was therefore considered desirable to design a second scattering unit which would (1) permit accurately measurable travel of the detector with respect to the beam axis and (2) localize the scattering gas in a narrow chamber to simplify the estimation of the detector aperture and to permit the detector to be in a highly evacuated region at all times. In addition to eliminating restrictive features of the first apparatus, the second unit was designed to incorporate significant improvements among which were elimination of sources of mercury vapor by using a rapid oil diffusion pump and substituting a thermocouple gage and an ionization gage for the previous McLeod gages, and the use of a self-contained Pirani gage to measure the pressure of gas in the scattering chamber. It is the primary purpose of the present paper to describe this new apparatus and to indicate its potentialities by showing its performance characteristics. The authors feel that the preliminary results obtained show that their first objective has been obtained, namely, the development of an apparatus of the same quality as those used in thermal velocity beam research.

The beam of high velocity neutral particles is made in a manner analogous to that used by Lamar and Luhr[10] for producing high velocity protons. A low voltage arc (20–60 volts, 0.5–1.5 amperes) is struck between a filament, at ground potential, and an anode in gas at 0.10–0.50 mm. pressure. Positive ions (0.10–0.30 ampere), produced primarily by electron collisions in the gas, are drawn to the cathode which is at a negative potential of 50–200 volts. Some of the positive ions (1.0–10.0 milliamperes) are drawn through a hemispherical nickel grid of 40 mesh screen mounted over an aperture in the cathode, and focused on the atom gun, an electrode with a small central canal. The negative potential on the atom gun may be varied from 200 to 2000 volts and some of the focused positive ions are neutralized in the canal of the gun, either at grazing incidence with its walls, or without actual physical contact.[13] The neutralization occurs without appreciable loss of kinetic energy, so that the beam emerging from the canal is a mixture of high velocity neutral atoms and positive ions which escaped neutralization. These ions are repelled by the top surface of the scattering chamber which acts as an ion mirror since it is at ground potential. Thus, the only high velocity particles entering the scattering chamber are neutral, accelerated gas molecules.

1. *Structural Details of the Apparatus*

The essential details of the present apparatus, with the exception of the electrical circuits, are shown in Figure 1. The arc section consists of two concentric brass tubes soldered to brass flanges at top and bottom. Hard solder is used except for the bottom joint of the outer tube, which is soft soldered. The section is provided with inlet and outlet tubes for circulating cooling water through the annular space, a ½ inch cathode lead tube, and a 1 inch tube which leads to the scattering section through the large valve, 13. The portion of the 1 inch tube adjacent to the arc section contains an inlet tube for introducing gas and a connection, 12, for a thermocouple gage which measures the pressure in this section.

The arc section is fastened to the scattering section by 16 bolts which thread into the top flange of the scattering section. The junction of the two sections is made vacuum tight by a lead gasket, 0.040″ thick. The filament adjuster, 1, is fastened to the arc section by a split steel plate and a similar arrangement of bolts and gasket.

It has been previously found[9] that the beam intensity frequently varied with the distance between the filament, 4, and the hemispherical grid, 5. A filament adjuster was therefore included in the present apparatus to permit accurate adjustment and measurement of the filament position. The adjuster is housed in a 5 inch length of brass tubing soft soldered into a brass flange. Vertical motion in vacuum is obtained by turning the knurled graduated knob at the top of the adjuster, since the drive shaft is pinned to a vacuum tight plate at the lower, free end of a bellows whose upper, fixed end is soldered peripherally to the inside of the housing. Eyelets, consisting of metal to glass seals, are used to bring leads from the filaments and anode, 2, through

[13] M. L. E. Oliphant and P. B. Moon, Proc. Roy. Soc. *A127*, 388 (1930).

the bottom plate. A radiation baffle is fastened below the plate to prevent the eyelets from being short circuited by evaporated and sputtered metal from the arc. The filament leads, protected from shorting to the anode by quartz sleeves, pass freely through holes in the anode as the bellows is compressed or extended. The required freedom of motion in this region with respect to the fixed anode is supplied by a phosphor bronze spring which serves as the anode lead. The adjuster permits about 1 inch of filament travel from a zero position about ½ inch above the grid. A metal index, fastened to the top of the drive shaft, indicates relative filament heights to

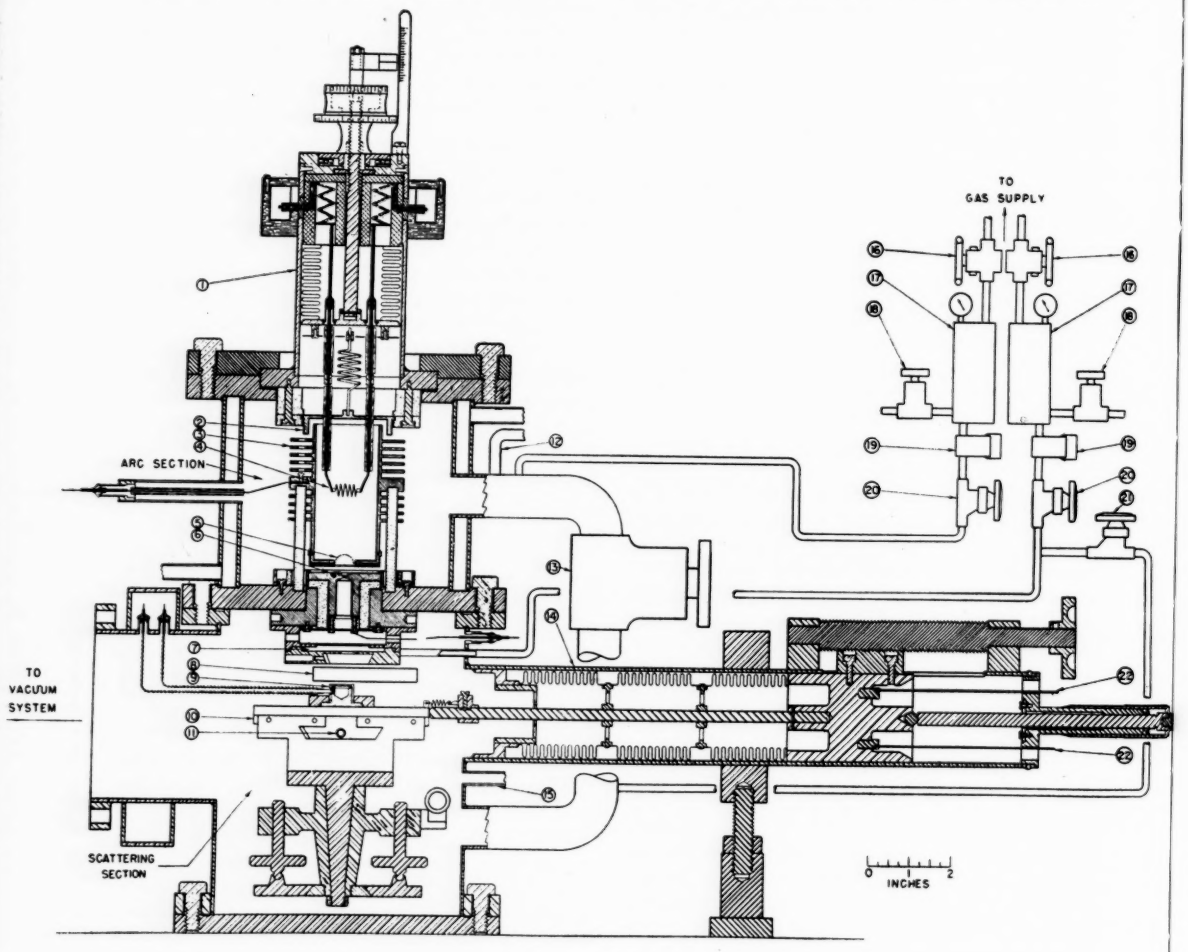

FIGURE 1. Details of high velocity molecular beam apparatus.

1. Filament adjuster
2. Anode
3. Cathode
4. Filament
5. Grid
6. Atom gun
7. Scattering chamber
8. Condensers
9. Detector
10. Longitudinal slide
11. Transverse slide
12. Thermocouple gage connection
13. Arc section by-pass valve
14. Longitudinal slide drive
15. Ionization gage connection
16. Gas supply shut-off valves
17. Ballast tanks
18. Gas supply pump-out valves
19. Throttle valves
20. Low pressure shut-off valves
21. Scattering chamber by-pass valve
22. Counterweight cables

twentieths of an inch on a graduated vertical standard; measurements to thousandths of an inch are read from the graduated drum of the knurled knob.

The apparatus has been designed to permit measurements of positive ion scattering by placing the atom gun at ground potential, the filament at variable positive potential, and the anode and cathode at appropriate potentials with respect to the filament, thereby eliminating the ion mirror action of the grounded scattering chamber. It is therefore necessary to provide for both flexibility and high voltage insulation of the filament and anode leads in the section of the filament adjuster above the vacuum tight bellows plate. This is accomplished by fastening coiled, stranded lead wires to the ends of the rigid leads from the filament and anode and encasing each of the three coils in wells drilled in a Lucite plastic cylinder which fits inside the adjuster housing and rests on the top bellows convolution. A Lucite disk covers the cylinder making it impossible for any portion of a coil to leave its well since the point at which the lower end of each coil is fastened to its rigid lead never leaves the well. At the top of the Lucite cylinder each stranded lead wire is held by the disk in a groove which leads into holes in the cylinder walls. The wire is fed through these holes and out through openings in the brass housing. Bakelite bushings prevent the leads from shorting to the brass walls. A Bakelite annular ring, suitably partitioned to segregate the three leads, is anchored to the housing and receives a conduit carrying leads from the filament and anode power sources. Soldered connections are made inside the partitions of the annular ring simply by removing the top cover.

The most suitable filaments were found to be standard oxide coated filaments used in type 866A mercury rectifier tubes. The filaments were kindly supplied without charge by the Radio Corporation of America.

The cathode, 3, was machined from aluminum and provided with cooling fins, one of which is $\frac{5}{16}''$ thick as compared with $\frac{1}{16}''$ for the remainder. The cathode is supported about $\frac{1}{10}''$ above the atom gun by three $\frac{1}{4}''$ diameter Isolantite ceramic rods. These pass through holes, spaced 120° apart, drilled through the bottom four fins and seat, at their upper ends, in the thick fin, while their lower ends rest in the floor of the arc section. The thick cathode fin also contains a set screw for fastening the cathode lead. The hemispherical screen grid, 5, which focuses positive ions on the atom gun, 6, is fastened over a $\frac{1}{2}''$ opening in the bottom of the cathode by a close fitting aluminum cap with a $\frac{1}{2}''$ center hole.

The anode is a cap machined from aluminum of size sufficient to permit at least $\frac{1}{10}''$ clearance between any point on it and any point on the cathode. It is provided with a ledge and peripheral boss to locate it between two rings of lava which are fastened to the flange of the filament adjuster. The arrangement insures proper alignment of the anode relative to the cathode. A second boss toward the center of the anode is tapped to receive the phosphor bronze spring lead.

The aluminum atom gun, shown in greater detail in Figure 2A, is $1\frac{3}{4}''$ in diameter across the face and $1\frac{3}{8}''$ long. The central canal is 0.020″ in diameter and 0.120″ long and is well rounded on the top to reduce discharge to the cathode. An insulating bushing, machined from a low vapor pressure plastic, Teflon, separates the atom gun from the aluminum insert which threads into the lower flange of the arc section and supports the scattering chamber, 7. The high voltage lead enters through a metal-glass seal in the scattering section and is connected to a brass washer held by spring contact against the bottom of the atom gun. A glass ring, fastened to the bottom of the aluminum insert, holds and insulates the high voltage washer contact. Pressure against the washer is obtained by forcing the atom gun down against the tension of the springs with a lava ring which bears on the face of the gun. The under surface of the gun face and the upper and under surfaces of the bushing into which the gun fits are made as smooth as possible to minimize leakage of gas from the arc section to the scattering section.

The scattering chamber consists of two parts which are soldered together. The upper section is cylindrical in shape and contains a 0.020″ entrance hole for the beam. Twenty $\frac{1}{4}''$ holes, equally spaced, have been drilled around the periphery of this section to permit rapid pumping of the region between the atom gun and the entrance to the scattering chamber. Two of the holes have been converted into a slot to permit passage of a glass vane, $\frac{1}{4}''$ wide, $1\frac{1}{2}''$ long and 1/32″ thick, which serves as a shutter to cut out the beam. The vane is moved in and out of the beam by a helical drive bellows arrangement not shown in the figure. The bottom section of the scattering chamber is $2\frac{3}{4}''$ square with an annular ring $2\frac{1}{2}''$ O. D. and $\frac{1}{4}''$ wide which telescopes

into the upper section. The bottom section contains the exit slot for the beam and two adjustable jaws which cover the slot to form a long, narrow slit. The important dimensions of the scattering chamber are shown in Figure 2A and in Figure 2B in which the bottom section of the scattering chamber has been turned through 90° to show the manner in which the jaws close over the exit

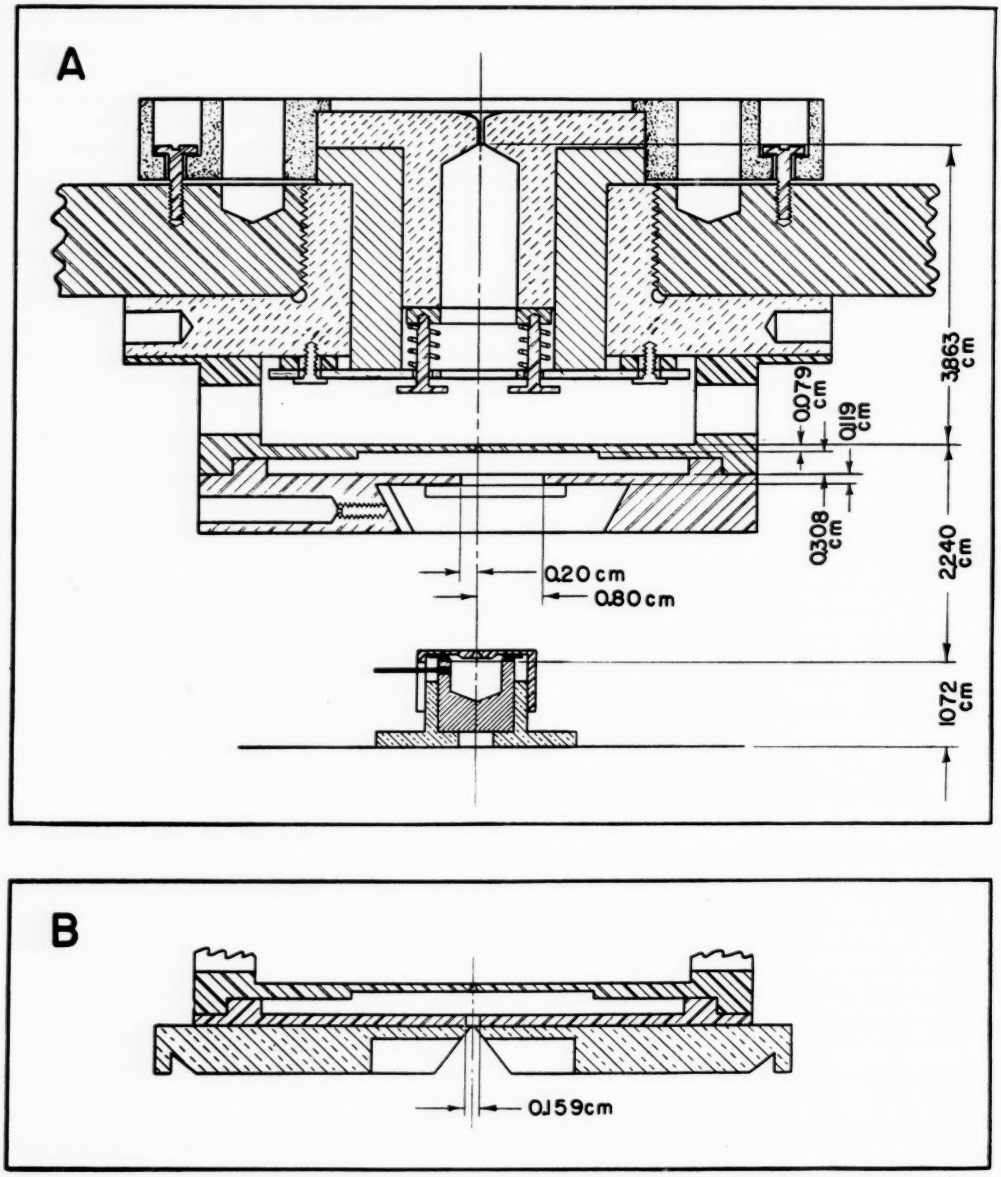

FIGURE 2. Details of atom gun, scattering chamber, and detector. A. Critical dimensions and distance relations. B. Scattering chamber exit slit jaws.

slot to form the exit slit. The pressure of the scattering gas in the region between the upper and lower sections of the scattering chamber is measured with a self-contained, compensated Pirani gage which also forms part of a circuit for measuring the temperature of the scattering gas. The details of this gage will be described under performance characteristics of the apparatus.

Two condenser plates, 8, sweep out of the beam any electrons or positive ions resulting from ionization action of high speed neutrals, as well as electrons emitted by metallic surfaces upon being struck by high energy particles. The plates are made of chromium plated brass and are 2½″ long, ⅜″ wide, and 1/32″ thick. They are so placed that the separation distance between the inside faces, 0.080″, is symmetrical about the beam, while the length is asymmetrically distributed about the beam, about ¾″ on the side toward the vacuum system. Potential differences up to 2000 volts may be impressed across the condensers.

The neutral beam intensity is measured by the detector, 9, (to be described later) which is mounted on a movable slide, 10. Longitudinal motion of the detector, in the direction parallel to the length of the exit slit, is obtained with a worm drive bellows arrangement, 14, which permits 2″ of travel, 0.3″ on the vacuum system side, and 1.7″ on the worm drive side of the beam axis. A micrometer measures the position of a hardened steel ball spun into the center of the movable piston actuated by the worm drive, thereby determining relative longitudinal positions of the detector to 0.0005″. A 50 pound counterweight is suspended from stranded brass cables, 22, over a pulley system, to balance the inward thrust of the atmosphere and permit easy motion of the worm drive. Transverse motion of the detector, in the direction perpendicular to the length of the exit slit, is obtained with a small micrometer bellows drive whose shaft is attached to the other movable slide, 11, of the detector carriage. This arrangement permits transverse motion of the detector of about 0.040″ on either side of the beam axis and enables relative positions to be determined to 0.0005″.

A 12 bolt, lead gasketed, flange combination connects the scattering section to the vacuum system consisting of a 4 inch oil fractionating diffusion pump, equipped with a water cooled baffle and backed with a Hypervac-20 forepump. The diffusion pump is protected against failure of its cooling system or excessive rise in forepressure.[14] The pumping speed of the vacuum system is estimated at 100 liters of air per second (the decrease from 275 liters per second, the nominal rating of the diffusion pump, is due to the presence of the baffle) and is sufficient to maintain a pressure of 6×10^{-5} mm. of helium in the scattering section with a helium pressure of 0.1 mm. in the arc section. A tube, 15, leads directly from the scattering section to an ionization gage which reads the low pressures in this section of the apparatus.

There are several features of the scattering section not shown in Figure 1 or previously described. These include six metal-glass seals for taking out the electrical leads from the scattering chamber Pirani gage network and the condensers and a Pyrex observation window 2½″ in diameter and ⅜″ thick which is clamped and gasketed in a 12 bolt flange on a large tubulation in the wall of the scattering section.

Separate gas supply systems are provided for the arc section and scattering chamber to permit scattering experiments for systems of unlike molecules. When possible, the gases are stored in small, high pressure steel cylinders, connected, through reducing valves, to the shut off valves, 16, which segregate the gas in the 500 cc. ballast tanks, 17, from the main supply, and are useful in preventing the pressure in the ballast tanks from building up in the event of a leak across the reducing valves of the storage cylinders. The flow of gas is regulated by the needle valves, 19, which have 500 : 1 tapers and provide accurate control of the pressure in the arc section and scattering chamber. The throttled gas streams enter the apparatus through a second pair of shut-off valves, 20. Pump-out valves, 18, are provided for evacuating the ballast tanks before filling them to a pressure slightly above atmospheric. A by-pass valve, 21, permits the scattering chamber to be quickly evacuated to obtain unscattered beam intensities for comparison with scattered beam intensities. All valves are packless, either diaphragm or bellows type, are made from brass forgings or machined from brass stock, and are individually tested for vacuum tightness.

Except for the diffusion pump protection device and a motor-generator set which supplies 100 volts and 200 volts D. C. for the anode and cathode, all electrical controls and power supplies are housed in a standard, mobile relay rack. Switches for the arc section are high voltage relays, operated from 6 volt transformers, which reduce

[14] I. Amdur, Rev. Sci. Inst. *18*, 66 (1947).

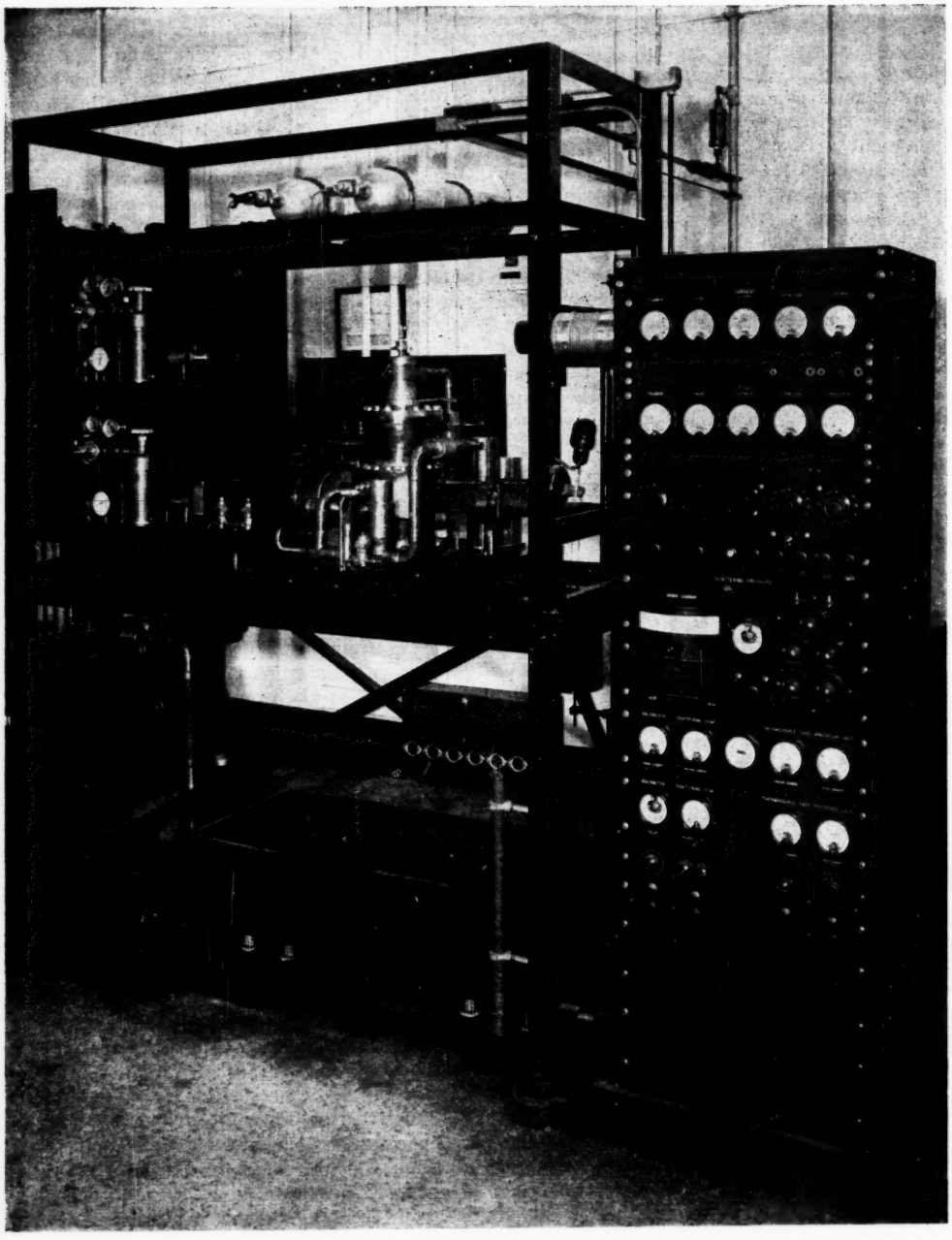

FIGURE 3. Apparatus and controls.

danger of shock as well as arcing difficulties encountered when slow moving, conventional switches are used in high voltage, high current circuits. The use of separate 100 and 200 volt D. C. generators (instead of the laboratory D. C. mains) permits the anode and cathode to remain at their same potentials relative to the filament when the atom gun is grounded and the filament raised to variable positive potential in the measurement of positive ion scattering. The beam apparatus has been mounted on a steel angle iron frame which rests on large bakelite supports and is electrically isolated, since water leads to and from the arc section and diffusion pump are interrupted with 12 inch sections of glass tubing. It is therefore possible to place the entire apparatus at positive or negative potential for special purposes such as a study of the effectiveness of the top surface of the scattering chamber as an ion mirror. Figure 3 is a photograph of the beam apparatus and its electrical controls. The diffusion pump is concealed by the panel of ballast tanks and valves for the gas supply systems, and a special galvanometer amplification arrangement[15] for measuring the detector response does not appear since it is in a section of the laboratory removed, as far as possible, from the electrical fields of the generators and power supplies.

2. *Performance Characteristics of the Apparatus*

a. *Detector Characteristics*

Two types of beam detectors have been built which operate by converting the kinetic energy of the high velocity beam particles into heat. One type is a single junction radiation vacuum thermocouple[16] and the other, a compensated vacuum bolometer.[17] Three vacuum thermocouples of different construction have been investigated. One, A, contains a circular receiver 0.279 cm. in diameter supported by one Chromel P and two constantan wires and masked with a circular opening 0.163 cm. in diameter; the second, B, contains a circular receiver 0.102 cm. in diameter supported by one Chromel P and one constantan wire and masked with a circular opening 0.051 cm. in diameter; and the third, C, which contains no receiver, was made by using a condenser discharge to butt weld a 0.0015 cm. diameter Chromel P wire, 0.318 cm. long, to a 0.0013 cm. diameter constantan wire, 0.318 cm. long, and is masked symmetrically about the weld with a rectangular opening, 0.051 cm. wide and 0.635 cm. long, whose long axis is perpendicular to the thermocouple. The welded detector has been used for most of the preliminary measurements with the present apparatus and is shown in Figure 2A in the axis of the beam path. The wires in thermocouples B and C are soldered to copper hemi-cylinders, separated by a mica spacer 0.001″ thick and pressed into a brass container which is insulated from the copper inserts by additional 0.001″ mica spacers. The bolometer, D, has a detecting element consisting of a blackened platinum wire 5.6×10^{-4} cm. in diameter and 0.476 cm. long which, like the welded thermocouple, acts as its own receiver. The detectors were tested by irradiation in vacuum with light from a standard lamp in accordance with previously described procedures.[16,17] The chief purpose in building the four detectors was to provide a method of varying the angular aperture of the detecting system since it has been shown[18] that experimentally determined cross-sections are functions of this aperture.

The results of room temperature tests on the four detectors are summarized in Table I. The angular apertures are the half angles subtended by the detector with respect to a point on the beam axis in the center of the gas confining region of the scattering chamber, namely, 0.253 cm. below the top surface of the upper section. These apertures differ by less than one per cent from values computed by averaging linearly over the 0.506 cm. distance which the beam travels in passing through the upper and lower sections of the scattering chamber. The radiant energy absorbed per second by each detector is given by $7.22 \times 10^{-5} \times 0.67 \times$ exposed area since the tabulated responses have been reduced to a common energy density falling per second on each detector, namely, 7.22×10^{-5} watts/cm.^{2} The detectors also have a common absorptivity, 0.67, which is characteristic of their aquadag coatings.

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[15] I. Amdur and H. Pearlman, Rev. Sci. Inst. *9*, 194 (1938).

[16] I. Amdur and H. Pearlman, Rev. Sci. Inst. *10*, 174 (1939).

[17] I. Amdur and C. F. Glick, Rev. Sci. Inst. *16*, 117 (1945).

[18] H. S. W. Massey and C. B. O. Mohr, Proc. Roy. Soc. *A141*, 434 (1933). H. S. W. Massey and C. B. O. Mohr, reference 4. R. G. J. Fraser and L. F. Broadway, Proc. Roy. Soc. *A141*, 626 (1933). L. F. Broadway, Proc. Roy. Soc. *A141*, 634 (1933). W. H. Mais, Phys. Rev. *45*, 773 (1934). S. Rosin and I. I. Rabi, Phys. Rev. *48*, 373 (1935).

TABLE I

CHARACTERISTICS OF BEAM DETECTORS

Detector	Angular Aperture	Exposed Area (cm.²)	Power Absorbed (watts)	Response (volts)	Sensitivity (volts/watt)
A	2.35 degrees	2.09×10^{-2}	1.01×10^{-6}	1.73×10^{-6}	1.71
B	44.0 minutes	2.04×10^{-3}	9.85×10^{-8}	6.37×10^{-7}	6.47
C	1.21 minutes	7.14×10^{-5}	3.45×10^{-9}	1.56×10^{-7}	45.2
D	28.9 seconds	2.67×10^{-4}	1.29×10^{-8}	1.28×10^{-6}	99.2

For each detector, the room temperature sensitivity is constant with respect to radiation density flux in the range 0 to 7.22×10^{-5} watts/cm.² by actual test.

In the case of a bolometer, the response is a function of the heating current. The value given for detector D in Table I is the maximum response and was obtained with a heating current of 0.92 milliamperes which produced a temperature rise of 55°.

b. *Arc Characteristics*

Since, to date, helium has always been used both in the arc section and in the scattering section, the performance characteristics of the apparatus refer to that gas. For other gases, the characteristics would differ in specific detail but not in general character.

After inserting a new filament, the large by-pass valve, 13, is opened and both sections of the apparatus are evacuated to a pressure below 10^{-5} mm. The filament is then "broken in" by careful heating to decompose its carbonate mixture coating into an active oxide coating. After the activation of a new filament, which requires about 15 minutes, the by-pass valve is closed and gas is admitted to the arc section at a pressure of about 0.4 mm. The anode and cathode are then shorted together and connected to the 100 volt D. C. source so that an arc is struck between the filament and the shorted electrodes. The shorting procedure has been found helpful in starting the arc, presumably because it provides a very much greater anode surface and eliminates the negative field which tends to return electrons to the filament. The arc is run in this manner until conditions become stable, after which the cathode is unshorted from the anode and operated at its proper negative potential. It is extremely important to prevent the anode voltage from rising much above 40 volts, otherwise bombardment of the filament by large currents of high energy positive ions will strip the oxide coating and deactivate the filament. The tendency toward high anode voltages is very pronounced when a new filament is first used, due, possibly, to gaseous impurities liberated from the metal surfaces upon bombardment by ions. The situation is remedied by evacuating the arc section through the large valve to eliminate the impure gas mixture. After several cycles in which the arc is restarted following the removal of impure gas, the anode voltage assumes a value of 40 volts or less and the arc continues to start and operate satisfactorily as long as air, or other harmful foreign gas such as water vapor, is not admitted to the arc chamber. This is accomplished by keeping the entire apparatus under high vacuum when the arc is not operating. It is because of the necessity for keeping the vacuum pumps in constant operation, that the protection device for the diffusion pump has been included in the apparatus. About 10 hours of arc operation are required to stabilize the arc and metal surfaces after insertion of a new filament, after which about an hour is required each time the arc is restarted after a shut down period exceeding several hours. After the 10 hour conditioning period, it is possible to decrease the gas pressure in the arc section to about 0.2 mm. to obtain larger detector responses without loss of arc stability. There is some evidence that the insertion of a copper liner inside the cathode results in lower anode voltages due, possibly, to the relative ease, compared to aluminum, with which copper sputters. The sputtering of the copper tends to produce a clean cathode surface, but since some of the sputtered metal deposits on the cooler turns of the filament and covers active oxide, much of the advantage with respect to increased filament life is probably lost. With proper precautions such as those described, filament life in excess of 100 hours can be obtained.

The following record of the first 19 running hours of an arc using a copper lined cathode and a filament which lasted for 98 running hours, illustrates average satisfactory arc behavior during the early life of a filament.

Typical atom gun-detector characteristics (obtained with the detector in the beam axis and the scattering chamber evacuated) for a properly functioning apparatus are shown in Figure 4 and correspond to the following arc conditions:

TABLE II

ARC CHARACTERISTICS FOLLOWING INSERTION OF A NEW FILAMENT

Time Hr.	Min.	Pressure Mm.	Filament Amp.	Filament Volts	Anode Amp.	Anode Volts	Cathode Amp.	Cathode Volts	Remarks
	0	5×10^{-6}	3.0	0.7	—	—	—	—	Activation of filament. Large by-pass valve open.
	2	1×10^{-4}	4.0	1.4	—	—	—	—	
	4	1×10^{-4}	5.0	2.2	—	—	—	—	
	7	5×10^{-4}	6.0	3.1	—	—	—	—	
	9	1×10^{-4}	7.0	3.75	—	—	—	—	
	14	1×10^{-4}	8.0	4.4	—	—	—	—	
	15	1×10^{-4}	7.0	3.75	—	—	—	—	
	18	0.42	7.0	3.7	1.0	21	Sh. to anode		Large by-pass valve shut. Gas in arc section.
	20	0.43	7.0	3.7	1.0	25	Sh. to anode		Arc turned off. Arc section pumped out.
	25	0.27	7.0	3.7	1.0	21	Sh. to anode		Arc restarted.
	39	0.43	7.1	3.7	0.85	52	0.08	140	Cathode unshorted.
	42	0.30	7.0	3.7	1.0	42	0.08	142	Arc turned off. Arc section pumped out
1	2	4×10^{-3}	7.0	3.7	—	—	—	—	
2	4	2×10^{-2}	7.0	3.7	—	—	—	—	Difficulty in outgassing.
2	35	0.31	8.0	4.3	0.45	40	0.08	140	Arc restarted.
3	50	0.40	8.0	4.3	0.50	33	0.08	144	
6	35	0.45	7.7	4.1	0.80	44	0.11	140	Arc turned off.
	0	0.42	7.5	3.9	1.0	24	Sh. to anode		Arc started next day.
	20	0.35	7.5	3.9	0.85	36	0.13	120	Cathode unshorted.
4	5	0.31	7.5	4.0	0.90	29	0.14	120	
5	45	0.41	7.0	3.7	0.87	30	0.22	120	
8	5	0.31	7.0	3.7	0.79	37	0.22	124	Arc turned off. Atom gun draws 2 ma. at 800 volts.
	0	0.42	7.5	4.2	0.90	38	0.22	120	Arc started next day.
2	3	0.41	7.5	4.2	1.0	29	0.25	118	Atom gun draws 2.1 ma. at 800 volts.
4	33	0.36	7.0	3.8	0.89	38	0.28	120	Atom gun draws 2.4 ma. at 800 volts.

pressure—0.25 mm.; filament—7.5 amp., 4.65 volts; anode—1.38 amp., 32 volts; cathode—0.30 amp., 170 volts. For a given arc pressure, curves of the same shape are obtained for different steady arc conditions.

The curves in Figure 4 can be fitted with the following relations:

$$I = 0.40 + 2.00 \times 10^{-3}V \text{ milliamperes} \quad \text{(A)} \quad (3)$$

$$E/I = 1.48 \times 10^{-2} e^{2.85 \times 10^{-3}V} \text{ microvolts/milliampere} \quad \text{(B)} \quad (4)$$

$$E = (5.92 \times 10^{-3} + 2.96 \times 10^{-5}V)\, e^{2.85 \times 10^{-3}V} \text{ microvolts} \quad \text{(C)} \quad (5)$$

where I, is the atom gun current, E, the electromotive force of the detector, and V, the atom gun voltage. For the particular geometry of the present apparatus, these results indicate that at low voltages the efficiency of neutralization (defined as the *fraction* of energy striking the atom gun which appears in the form of high speed neutrals) decreases with increasing voltage while at higher voltages the efficiency increases, due, possibly, to improved focusing by the screen grid. This conclusion is obtained in the following way.

The fraction, F, of atom gun energy which is converted into neutral beam energy is $aE/(IV)$ where a is a voltage independent constant characteristic of apparatus geometry. This fraction is given by

$$F = aE/(IV) = be^{2.85 \times 10^{-3}V}/V \quad (6)$$

where $b = 1.48 \times 10^{-2}a$, and the rate of change of the fraction by

$$dF/dV = F(2.85 \times 10^{-3} - 1/V). \quad (7)$$

This rate of change is negative below 350 volts and positive above, suggesting the previously mentioned change in efficiency of neutralization with increasing voltage.

For a different set of arc conditions, namely: pressure—0.24 mm.; filament—7.5 amp., 4.5 volts; anode—0.81 amp., 40.5 volts; cathode—0.24 amp., 172 volts, the same general results were obtained, as shown by the following relations:

$$I = 0.32 + 1.93 \times 10^{-3}V \text{ milliamperes} \quad (8)$$

$$E/I = 1.57 \times 10^{-2} e^{2.83 \times 10^{-3}V} \text{ microvolts/milliampere} \quad (9)$$

$$E = (5.03 \times 10^{-3} + 3.03 \times 10^{-5}V)\, e^{2.83 \times 10^{-3}V} \text{ microvolts.} \quad (10)$$

It is possible to obtain stable arc conditions and reproducible atom gun-detector characteristics for arc section pressures ranging from about 0.08

to 0.50 mm. The neutral beam intensity, however, is a fairly strong function of this pressure. For example, for an unscattered beam at 800 volts, an arc section pressure of 0.21 mm. produces a maximum detector response which decreases by 40 per cent at 0.42 mm. and by 20

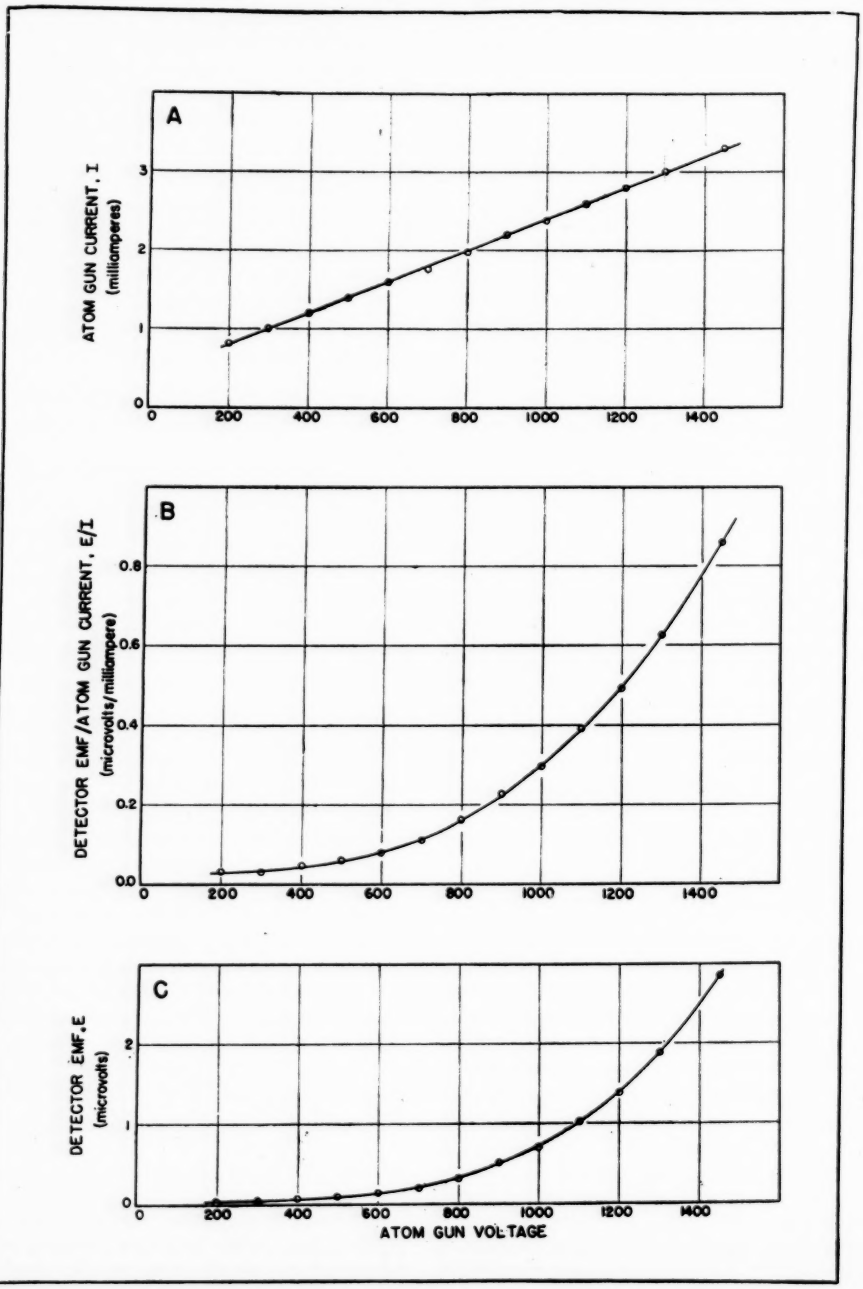

FIGURE 4. Typical atom gun-detector characteristics.

per cent at 0.09 mm. The decrease at higher pressures is probably due to scattering of high velocity ions on their way to the atom gun, and the decrease at low pressures, to the smaller number of positive ions which pass through the screen in preference to being neutralized at the cathode walls, as suggested by enhanced cathode currents at low pressures. Whenever possible, therefore, an arc section pressure of about 0.2 mm. is used to obtain maximum detector responses for any given set of arc conditions.

c. *Pirani Gage Characteristics*

The self-contained Pirani gage which measures the pressure of gas in the scattering chamber has been described in detail elsewhere.[19] It consists of a platinum wire, 1.37×10^{-3} cm. in diameter and 4.57 cm. long, suspended between the upper and lower sections of the chamber. A platinum wire compensator, in thermal contact with the walls of the scattering chamber, and two fixed manganin resistors are combined with the gage wire to form a Wheatstone bridge network which is in balance when the gage wire is about 2 degrees hotter than the compensator. For a given compensator temperature and a given gas, the scattering pressure is a single valued function of the bridge current at balance. Over a limited pressure range, it is possible to use an empirical relation which, for the present type of gage network, has the simple form

$$P = aI_B^2 - b \tag{11}$$

where P is the pressure and I_B, the bridge current at balance. The constants a and b are characteristic of each gas and depend only upon the temperature. This temperature dependence may be deduced in the following manner.

When current, I, flows through the Pirani gage wire of resistance R, the energy balance may be written in the form

$$I^2R = A + B + C + D \tag{12}$$

where

A = radiation loss
B = wire conduction loss at zero pressure
C = additional wire conduction loss at pressure P
D = gas conduction loss at pressure P.

The heat flow problem formulated in Equation (12) has been previously analyzed in discussing the characteristics of a compensated bolometer,[17] and the results obtained indicate that, for the present gage, C may be treated as a constant small fraction (about 0.1) of D for pressures up to about 0.1 mm., the probable upper limit of scattering pressure which will be used in the apparatus. Equation (12) may therefore be written

$$I^2R = I_0^2R + K\alpha P\overline{\Delta t}/\overline{T}^{\frac{1}{2}} \tag{13}$$

where I_0 is the current through the gage wire at zero pressure at bridge balance, α, the accommodation coefficient of the gas on the gage wire, $\overline{\Delta t}$, the average temperature excess of the gage wire with respect to the compensator at temperature t, $\overline{T}$, the average gas temperature (which may be set equal to $273 + t + \overline{\Delta t}/2$ or $274 + t$), and K, a constant for each gas which is independent of both temperature and pressure.

The current which is read in the apparatus is not the gage wire current, I, but the total bridge current, I_B, whose relation to I is expressed by

$$I = \frac{I_B}{2.525\,[1 + 2.12 \times 10^{-3}(t - 26)]}. \tag{14}$$

The gage resistance, R, and the average temperature excess, $\overline{\Delta t}$, are temperature functions given by

$$R = 36.483\,[1 + 3.60 \times 10^{-3}(t - 26)] \text{ ohms} \tag{15}$$

and

$$\overline{\Delta t} = 2.114\,[1 + 3.63 \times 10^{-3}(t - 26)] \text{ degrees.} \tag{16}$$

Since 26° C. was the reference temperature at which the bridge characteristics were determined, the corresponding reference value for $\overline{T}$ must be taken as 300° K., whereupon Equation (13) reduces to

$$I_B^2 = I_{B(0)}^2 + K'\alpha P\,[1 + 2.60 \times 10^{-3}(t - 26)] \tag{17}$$

where $K' = K/46.88$ and where $I_{B(0)}$ by actual measurement is found to conform to the relation

$$I_{B(0)} = 1.977\,[1 + 3.69 \times 10^{-3}(t - 26)] \text{ milliamperes.} \tag{18}$$

Equations (17) and (18) lead to the following equation for converting a bridge current, I_B, measured at temperature t and pressure P, to a corrected current, I_B^*, referred to 26° C and the same pressure:

$$I_B^{*2} = \frac{I_B^2}{1 + 2.60 \times 10^{-3}(t - 26) - 18.7 \times 10^{-3}(t - 26)}. \tag{19}$$

Equation (17) does not transform directly into Equation (11) because the accommodation coeffi-

[19] I. Amdur, M. M. Jones and H. Pearlman, J. Chem. Phys. *12*, 159 (1944).

cient, α, is pressure dependent in the range of present interest, 0 — 0.1 mm.[20] Yet, calibration results for ten gases, when corrected by Equation (19) to 26° C., gave very satisfactory straight line plots of P vs I_B^{*2} in the pressure range 0.008 — 0.12 mm., showing that the form of Equation (11) is valid. The ratios of b/a did not equal $I_{B(0)}^{*2}$, (1.977 ma.),[2] however, and the straight line relation must therefore be considered empirical. That it is obtained at all is probably due to the fact that no attempt was made to force the constants a and b or the ratio b/a to adhere to theoretical or predetermined values and that the moderate pressure dependence of α was therefore absorbed in the mutual departure of a and b from such values.

The calibration results for the ten gases are summarized in Table III in terms of the values of the constants a and b in Equation (11) which define the best straight lines through the experimental points corrected to 26° C. Fifty experimental values were available in the desired pressure range, of which two, one each for helium and xenon, were discarded as being excessively in error. The second column lists the number of experimental values which were used in determining the constants for each gas, while the last two columns record absolute deviations of calculated pressures from experimental values.

TABLE III

PIRANI GAGE CALIBRATION AT 26° C. FOR 0.12 MM > P > 0.008 MM.

Gas	No. of points	a	b	Av. Dev.	Max. Dev.
		mm.-(ma.)^2	mm.	%	%
Helium	6	0.01093	0.04500	1.4	3.5
Neon	5	0.01362	0.05466	1.0	1.9
Argon	4	0.01567	0.06323	1.8	2.5
Krypton	5	0.02245	0.09160	0.9	1.4
Xenon	5	0.02776	0.1160	1.4	2.7
Hydrogen	5	0.006600	0.02700	1.6	2.5
Deuterium	5	0.007335	0.03054	0.8	1.3
Nitrogen	5	0.009813	0.04023	1.4	2.3
Carbon monoxide	4	0.009771	0.04070	0.2	0.4
Oxygen	4	0.01006	0.04027	0.8	1.2

At any temperature two readings of the bridge current are required to determine the scattering pressure. One reading, $I_{B(0)}$, at zero pressure serves to define t through Equation (18), so that the other reading, I_B, at pressure P, may be corrected to I_B^* at 26° C. through Equation (19). The values of a and b appropriate to the gas are then selected from Table III and combined with I_B^* to calculate P from Equation (11).

[20] I. Amdur, J. Chem. Phys. *14*, 339 (1946).

d. *Scattering Section Pressure Characteristics*

Whenever possible, the intensity of a beam which has been attenuated by passing through a layer of scattering gas is referred to the intensity of the unscattered beam to eliminate the difficult and unnecessary task of measuring absolute intensities. When it is not feasible to obtain an intensity measurement at essentially zero scattering pressure, the ratio of intensities at two known pressures serves equally well. This is illustrated by the following expressions for estimating the scattering mean free path at unit pressure and 273° K., L_v, of a beam particle which has traversed a uniform scattering region of length x:

Case 1—Scattered intensity, I, at pressure P and temperature T; reference intensity, I_0, at zero pressure.

$$I/I_0 = \exp\,[-\,(273x/L_v)(P/T)]. \qquad (20)$$

Case 2—Scattered intensity, I_1, at pressure P_1 and temperature T_1; reference intensity, I_2, at pressure P_2 and temperature T_2.

$$I_1/I_2 = \exp\,[-\,(273x/L_v)(P_1/T_1 - P_2/T_2)]. \qquad (21)$$

In the present apparatus the 0.020″ hole in the atom gun permits sufficient gas to flow from the arc section into the scattering section to cause significant scattering of the beam even when gas is not admitted into the scattering chamber, and the equivalent of Equation (21) must be used for mean free path calculations. The relation of the scattering section pressure to the arc section pressure under these conditions was determined for helium from readings of the thermocouple and ionization gages and found to conform to the type of relation required for free molecule flow. The actual relation may be written

$$P_{SS}^{\circ} = 6.11 \times 10^{-4} P_{AS} \quad (0.10 \text{ mm.} < P_{AS} < 0.43 \text{ mm.}) \qquad (22)$$

where P_{SS}° is the scattering section pressure of helium due to pressure P_{AS} in the arc section when gas is not admitted to the scattering chamber. Similarly, by eliminating the flow of helium into the arc section and admitting gas to the scattering chamber, the increase in scattering section pressure, ΔP_{SS}, due to gas in the scattering chamber at pressure P_{SC} was determined from readings of the Pirani and ionization gages. The actual relation was found to be

$$\Delta P_{SS} = 1.41 \times 10^{-3} P_{SC} \quad (0.009 \text{ mm.} < P_{SC} < 0.10 \text{ mm.}) \qquad (23)$$

so that the total scattering section pressure of

helium when gas is present in both the arc section and scattering chamber is

$$P_{SS} = 6.11 \times 10^{-4} P_{AS} + 1.41 \times 10^{-3} P_{SC}. \quad (24)$$

As previously indicated, the reference intensity measurement (when gas is not admitted to the scattering chamber) is accompanied by weak scattering of the beam through the distance from the atom gun exit to the detector, 6.103 cm., due to pressure P_{SS}° as given by Equation (22). When gas is admitted to the scattering chamber, the scattering of the beam is no longer uniform due to the large difference in pressure existing inside the scattering chamber in comparison with that outside. Rosin and Rabi[15] have shown that this type of non-uniform scattering may be treated by resolving it into component parts which, in the present case, may be characterized as follows:

1. Scattering from the atom gun exit to the scattering chamber entrance through 3.863 cm. of gas at pressure P_{SS} as given by Equation (24).

2. Scattering in the cloud (cloud 1) formed by gas escaping from the entrance hole of the scattering chamber.

3. Scattering in the circular entrance channel (0.051 cm. diameter, 0.079 cm. long) of the scattering chamber.

4. Scattering in the scattering chamber proper, a distance of 0.427 cm. from the rear of the entrance hole to the slit jaws. (The area of the slot above the jaws is sufficiently large and its length parallel to the beam axis sufficiently short, to render negligible pressure drops occurring in it when the slit jaws are in position.

5. Scattering in the exit slit which is actually a short, narrow rectangular channel. That the slit has significant length is due to the fact that the defining jaws do not have perfect knife edges. The cross sectional area of the channel is that of a rectangle, 1.00 cm. by 0.0025 cm., and its length is estimated to be 0.01 cm.

6. Scattering in the cloud (cloud 2) formed by gas escaping from the exit slit of the scattering chamber.

7. Scattering from the scattering chamber exit slit to the detector through 1.734 cm. of gas at pressure P_{SS} as given by Equation (24).

The pressure distribution in the circular cross section entrance channel of the scattering chamber may be computed from formulas and tables given by Clausing[21] for the free molucule flow of gases through a variety of openings. As gas flows outward from the scattering chamber through this channel toward the atom gun, the pressure drops linearly in the 0.079 cm. length from $0.79P_{SC}$ on the inner side to $0.21P_{SC}$ on the outer side so that the average pressure in the channel is $0.50P_{SC}$. An exact method for calculating the pressure distribution in the cloud at the entrance channel of the scattering chamber does not seem to exist. Fortunately, the scattering in the cloud is a small fraction of the total and very approximate estimates are sufficient. The assumption of Rosin and Rabi, that the pressure in the cloud at its origin is half the pressure at the end of the channel, will be taken as the starting point. In the present case, this leads to an origin value of $0.105P_{SC}$. Since most of the scattering of the beam will be confined to very small angles, the inverse square intensity law, which is a special case of the cosine law of molecular effusion, will be used to estimate pressures in the cloud at distances large in comparison with the channel radius. This leads to

$$P_1(r) = 0.21P_{SC}(0.0255/r)^2 \quad (r >> 0.0255 \text{ cm.}) \quad (25)$$

where $P_1(r)$ is the pressure in cloud 1 at a distance of r cm. from its origin. Equation (25) shows that the pressure in the cloud 0.310 cm. from its source has already been reduced to a value indistinguishable from the increase in scattering section pressure due to gas in the scattering chamber, namely, $1.41 \times 10^{-3} P_{SC}$. The variation of pressure in cloud 1 over the entire 0.310 cm. distance is adequately represented by the empirical relation

$$P_1(r) = 0.105P_{SC} \exp(-13.9r) \quad (26)$$

As gas flows outward from the scattering chamber through the rectangular cross section exit slit toward the detector, the pressure drops linearly in the 0.01 cm. length from $0.80P_{SC}$ on the inner side to $0.20P_{SC}$ on the outer side, so that the average pressure in the short channel is $0.50P_{SC}$. In analogy with the procedure used for cloud 1, the pressure at the origin of the cloud emanating from the exit slit, cloud 2, will be taken as $0.10P_{SC}$ and the pressure at distances large compared with the longest beam dimension (about 0.05 cm.) will be computed from

$$P_2(r) = 0.20P_{SC}[0.0025/(\pi r^2)]. \quad (27)$$

Equation (27) predicts that the pressure in cloud 2 will reach the background value of $1.41 \times 10^{-3} P_{SC}$ at $r = 0.336$ cm. The empirical relation

[21] P. Clausing, Physica *9*, 65 (1929).

which adequately represents the pressure distribution in the cloud over the entire 0.336 cm. distance is

$$P_2(r) = 0.100P_{SC} \exp(-12.7r). \quad (28)$$

Equation (21) may now be converted into a form applicable to the present scattering situation by rewriting it as

$$I_1/I_2 = \exp[-(273/L_v)(\Sigma x_i P_i/T_1 - 3.73 \times 10^{-3} P_{AS}/T_2)] \quad (29)$$

where L_v must be expressed in cm. and where $\Sigma x_i P_i$ is the sum of the effective values of xP_1 for the seven component parts which constitute the total scattered beam when gas is admitted to the scattering chamber. In detail

$$\Sigma x_i P_i = 3.863 P_{SS} + \int_0^{0.310} P_1(r)dr + 0.079 \times 0.50\, P_{SC} + 0.427 P_{SC} \quad (30)$$
$$+ 0.01 \times 0.50 P_{SC} + \int_0^{0.336} P_2(r)dr + 1.734 P_{SS}$$

which, upon evaluating the integrals and eliminating P_{SS} through Equation (24), simplifies to

$$\Sigma x_i P_i = 3.42 \times 10^{-3} P_{AS} + 0.495 P_{SC}. \quad (31)$$

The term $0.495P_{SC}$ in Equation (31) represents the total scattering contribution of the gas which is admitted to the scattering chamber. The scattering in both clouds contributed but 3 per cent to this total.

Equations (29) and (31) may be combined to give an equation from which L_v may be calculated from experimentally observable quantities, namely,

$$I_1/I_2 = \exp[-(273/L_v)(3.42 \times 10^{-3} P_{AS}/T_1 + 0.495 P_{SC}/T_1 - 3.73 \times 10^{-3} P_{AS}/T_2)]. \quad (32)$$

In practice, $3.73 \times 10^{-3} P_{AS}$ is not likely to exceed 0.0015 (corresponding to a probable maximum arc pressure of 0.4 mm.) and $0.495P_{SC}$ is not likely to fall below 0.004 (corresponding to a probable minimum scattering chamber pressure of 0.008 mm.). Since T_1 and T_2 will seldom differ by more than one or two degrees, the ratio of $|\, 3.42 \times 10^{-3} P_{AS}/T_1 - 3.73 \times 10^{-3} P_{AS}/T_2 \,|$ to $0.495 P_{SC}/T_2$ will be about 1 : 32 in the most unfavorable case and $(3.42 \times 10^{-3} P_{AS}/T_1 - 3.73 \times 10^{-3} P_{AS}/T_2)$ may be replaced by $-3.1 \times 10^{-4} P_{AS}/T_1$ with insignificant loss in accuracy so that Equation (32) may be simplified to

$$I_1/I_2 = \exp[-135(P_{SC} - 6.3 \times 10^{-4} P_{AS})/(L_v T_1)]. \quad (33)$$

It must be remembered that Equation (33) applies only if the following conditions are satisfied:

1. Measurement of the reference intensity, I_2, must be made with no gas admitted to the scattering chamber.
2. T_1 must be approximately equal to T_2.
3. P_{SC} must not be appreciably less than 0.008 mm.
4. P_{AS} must not be appreciably greater than 0.4 mm. Conditions 2, 3, and 4 will usually be automatically fulfilled because of present apparatus characteristics. In the event that condition 1 is not fulfilled, it is possible to modify Equation (33) to correspond to specific operating conditions. For example, if an experiment were conducted under the following conditions:

1. Scattered intensity, I_1, at scattering chamber pressure P_{1SC} and temperature T_1,
2. Reference intensity, I_2, at scattering chamber pressure P_{2SC} and temperature T_2,
3. T_1 approximately equal to T_2,
4. Arc section pressure, P_{AS}, unchanged during measurement of I_1 and I_2,

the appropriate equation for estimating L_v would be

$$I_1/I_2 = \exp[-(135/L_v)(P_{1SC}/T_1 - P_{2SC}/T_2)]. \quad (34)$$

Although the pressures in Equations (33) and (34) may be expressed in any convenient units, it is customary to use millimeters of mercury, in which case L_v is the mean free path in cm. at 1 mm. pressure and 273° K. For the present type of scattering system, the cross section, S_v, corresponding to L_v is given by

$$S_v = 1/(nL_v) \quad (35)$$

where n is the number of scattering particles, 3.54×10^{16}, per cc. at 1 mm. and 273° K. if L_v is in cm. at 1 mm. and 273° K. Equations (33) and (34) may therefore be converted to

$$I_1/I_2 = \exp[-4.78 \times 10^{18}(P_{SC} - 6.3 \times 10^{-4} P_{AS})\, S_v/T_1] \quad (36)$$

and

$$I_1/I_2 = \exp[-4.78 \times 10^{18} S_v (P_{1SC}/T_1 - P_{2SC}/T_2)] \quad (37)$$

respectively, for calculating S_v in cm.^{2} from pressures expressed in mm.

e. *Preliminary Scattering Results*

Preliminary scattering measurements for helium in helium have been made for atom gun

DETECTOR EMF (microvolts)

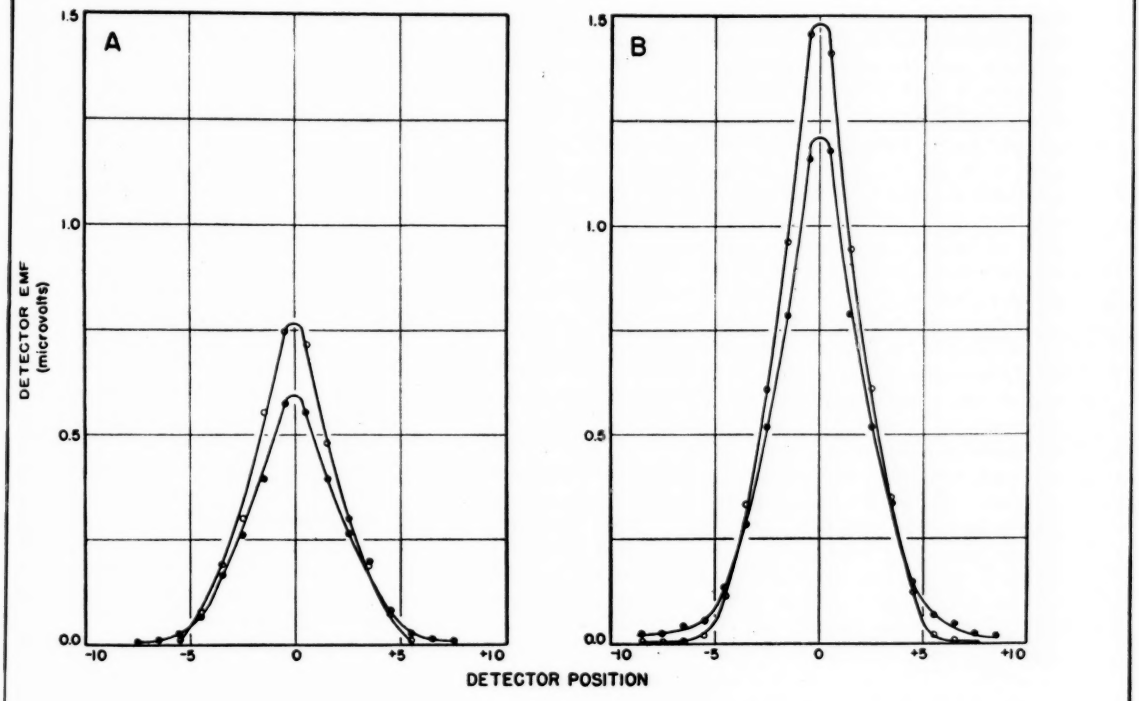

FIGURE 5. Scattering of helium in helium. (Reference beam—○; scattered beam—●) A, 1000 volt beam; B, 1200 volt beam.

voltages in the range 600–1200 volts. In every case the scattered and reference beams were probed in the transverse direction in steps of 0.001″ to obtain profiles showing the angular intensity distribution. All reference intensity measurements were made with no gas admitted to the scattering chamber. Typical results for 1000 and 1200 volts (atom gun currents, 3.24 ma. and 3.65 ma., respectively) are shown in Figure 5 where the abscissa is the transverse position of the detector (in thousandths of an inch) relative to the point of maximum intensity. The arc characteristics were the same for both sets of measurements, namely: pressure—0.27 mm.; filament—7.3 amp., 4.40 volts; anode—0.82 amp., 41 volts; cathode—0.24 amp., 160 volts. Similarly, the pressure, P_{SC}, and temperature, T_1, of the helium in the scattering chamber were the same in both sets, 0.0165 mm., and 281.7° K. The temperature, T_2, of the very low pressure gas in the scattering section during measurement of reference intensities was also 281.7° K.

If a true point detector were used to probe the intensity of the beam, because of the circular cross section of the scattering chamber entrance channel, the transverse and longitudinal profiles of the beam would be the same within the average angular limit, about 7 degrees, determined by the geometry of the exit slit. However, the detector used to obtain the results in Figure 5 has an effective exposed area of a rectangle 0.0014 cm. wide and 0.051 cm. long. Since the long dimension is parallel to the length of the exit slit, transverse motion is essential to obtain

measurements under aperture conditions (1.21 minutes) determined by the 0.0014 cm. dimension.

The curves of Figure 5 show that the resolution of the detector is sufficiently high to obtain a precise pattern of the angular distribution of beam intensity in the very narrow range of angle to which most of the scattering is confined. For example, at both 1000 and 1200 volts, about 90 per cent of the total reference beam intensity is confined to $\pm$ 0.0035″ of detector travel with respect to the maximum, corresponding to a symmetrical angular spread of 15.4 minutes about the beam axis. After scattering through 0.0165 mm. of helium, about 75 per cent of the total reference beam intensity is retained in this same region at both voltages.

By using ratios of peak intensities, it is possible to calculate L_v and S_v at 1000 and 1200 volts from Equations (33) and (36) and the values obtained are characteristic of the aperture determined by the width of the detector. If, instead of peak intensities, areas under the curves are used, mean free paths and cross sections are obtained which are characteristic of larger apertures determined by the abscissas which bound the areas. Thus, the use of a single movable detector of sufficiently small aperture can be used to obtain total collision scattering information characteristic, either of its own aperture, or of a series of detectors of larger aperture. This procedure is illustrated by the results in Table IV which compares values of L_v and S_v calculated from peak intensities with those calculated from areas corresponding to $\pm$ 0.0035″ of detector travel.

TABLE IV

EFFECT OF APERTURE ON L_v AND S_v

	Peak Intensities		Integrated Intensities	
Voltage	1000	1200	1000	1200
I_1/I_2	0.778	0.818	0.801	0.833
Aperture, min.	1.21	1.21	15.4	15.4
L_v, cm. (at 1 mm. and 273° K.)	0.0312	0.0390	0.0353	0.0428
S_v, 10^{-16} cm.^{2}	9.06	7.24	8.00	6.60

Although extended measurements on the scattering of high velocity neutral helium atoms are contemplated, the preliminary typical results of Table IV, coupled with previous collision cross section measurements of Amdur and Pearlman,[12] indicate that the present apparatus is capable of supplying quantum mechanical cross sections corresponding to the limit of zero aperture. For example, at 1000 volts, the previously determined value of S_v was 0.9×10^{-16} cm.^{2} at an average aperture of 2.25 degrees. When this aperture is reduced by about 9 fold, to 15.4 minutes, a correspondingly large increase (about 9 fold) in S_v results and a value of 8.00×10^{-16} cm.^{2} is obtained. Massey and Mohr[18] have shown, on theoretical grounds, that a large increase in total cross section should occur as the aperture is decreased from large values where the scattering is classical, to small values where diffraction arising from the de Broglie wave character of the scattering system produces extremely high intensity small angle scattering. They further show that the cross section should approach a finite limit as the aperture approaches zero, instead of increasing indefinitely as predicted by classical theory. The results of Table IV confirm the existence of this limit, since a further decrease in aperture of approximately 13 fold (from 15.4 min. to 1.21 min.) merely increases S_v by 13 per cent, from 8.00×10^{-16} cm.^{2} to 9.05×10^{-16} cm.^{2} In general, it is felt that the character of the curves in Figure 5 (high symmetry and overall small scattering of points) and the results of Table IV confirm the expectation that the present apparatus will be capable of supplying scattering results for high velocity beams of the same high quality as those obtained by Mais[18] and by Rosin and Rabi[18] for thermal velocity beams of alkali metals.

D. Summary

An apparatus has been described for producing and scattering high velocity neutral particle beams with energies of 200 to 2000 electron volts. Special features of the apparatus include the use of detectors with small angular apertures, as low as 28.9 seconds of arc, isolation of the scattering gas in a small fraction of the distance between beam source and detector in order to define the angular aperture more sharply, and facilities for accurately probing the beam to obtain measurements of intensity as a function of angle. Extended tests of the apparatus have been made and performance characteristics of vital sections have been given to illustrate the quality of control of which the apparatus is capable and the range of variables which can be covered. Typical preliminary results for 1000 and 1200 volt helium atoms scattered in helium have been presented and analyzed. It is concluded that the present apparatus is capable of supplying scattering information of the same high quality as that available for thermal velocity beams.

E. Acknowledgments

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RECORDS OF MEETINGS

One Thousand Two Hundred and Ninety-Sixth Meeting

OCTOBER 11, 1944—STATED MEETING

The Academy met at its House at 8:30 P. M.

The President in the Chair.

There were present fifty-nine Fellows and twenty guests.

The records of the meeting of May 10 were read and approved.

The Corresponding Secretary reported the receipt of letters accepting Fellowship from the following: Isadore Amdur, Adolf Augustus Berle, Jr., Douglass Vincent Brown, William Bell Dinsmoor, Henry Grattan Doyle, Maxwell Finland, Carl J. Friedrich, Raymond Blaine Fosdick, Paul Rupert Gast, Walter Gropius, Arthur Robert von Hippel, Ernest Martin Hopkins, Columbus O'Donnell Iselin, James Rhyne Killian, Jr., Ronold Wyeth Percival King, Clyde Kay Maben Kluckhohn, Eugene Markley Landis, Ambrose Lansing, Elias Avery Lowe, Saunders MacLane, William Malumud, Richard von Mises, Charles Rufus Morey, John von Neumann, Linus Carl Pauling, Hugh Miller Raup, Albert Charles Smith, Harald Ulrik Sverdrup, Karl Terzaghi, George Widmer Thorn, La Rue Van Hook, Karl Vietor, Sarah Wambaugh, Edgar Bright Wilson, Jr., Charles Edward Wilson, Herbert Eustis Winlock; and from Amado Alonso, Ezequiel Ordoñez, and Daniel Cosío Villegas accepting Foreign Honorary Membership; also letters declining Fellowship from Vera Micheles Dean and Leverett Saltonstall.

He also reported the receipt of a letter from Melvin T. Copeland resigning Fellowship.

The Corresponding Secretary reported that the Council had accepted the Report of the Committee of the Permanent Science Fund in which four grants in aid had been made:

1. To Charles A. Berger, Professor of Cytology and Head of Biology Department, Fordham University, for assistance in continuing studies of the effect of nutrients upon Chromosomes, $500.

2. To T. T. Chen, Lecturer in Zoology, University of California, Los Angeles, for assistance in further studies on Cytogenetics of Protozoa, $250.

3. To C. T. Hurst, Director of Museum, Western State College of Colorado, for assistance and necessary travel in expanding his archaeological explorations in Colorado, $300.

4. To J. Schiller, Fearing Research Laboratory, Free Hospital for Women, Boston, for expendable materials and assistance in studies on steroid hormones, $500.

After the introduction of new Fellows, the following communication was presented:

Howard Mumford Jones: *The American Academy: its Status and Prospects.*

The following papers by P. W. Bridgman were read by title: *The Compression of 61 Solid Substances to 25,000 kg/cm², Determined by a New Rapid Method; The Compression of Twenty-one Halogen Compounds and Eleven Other Simple Substances to 100,000 kg/cm².*

The meeting was dissolved at 9:50 P. M.

One Thousand Two Hundred and Ninety-seventh Meeting

NOVEMBER 8, 1944—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were sixty-two Fellows and thirty-one guests present.

The records of the meeting of October 11 were read and approved.

The Corresponding Secretary announced that the President had been authorized to appoint a commission of five Fellows to study the functions of the Academy.

The Corresponding Secretary reported that Reid Hunt and Archibald T. Davison have been transferred to the status of Fellows Emeriti.

Frederick H. Pratt called attention to E. L. Mark's sixtieth anniversary as a Fellow and stated that the Council had voted to send him a note of congratulation.

After the introduction of new Fellows the following communications were presented:

Edwin J. Cohn: *Blood Is a Very Special Juice.*

Charles A. Janeway: *The Use of Blood and Blood Derivatives in Medicine.*

Franc D. Ingraham: *The Use of Blood Derivatives in Surgery.*

The meeting was dissolved at 10:25 P. M.

One Thousand Two Hundred and Ninety-eighth Meeting

DECEMBER 13, 1944.—STATED MEETING

The Academy met at its House at 8:25 P. M.

The President in the Chair.

This meeting had been designated as Ladies' Night, and there were present more than two hundred and fifty Fellows and guests.

The records of the meeting of November 8 were read and approved.

The following communication was presented:

Francis Henry Taylor: *The Problem of Salvage and Restitution of the Artistic Treasures of Europe.*

An exhibit, *Quartz Goes to War,* was on view in the office, Mr. Ernest R. Bohro, of the August E. Miller Laboratories, being the demonstrator.

The meeting was dissolved at 9:40 P. M.

One Thousand Two Hundred and Ninety-ninth Meeting

JANUARY 10, 1945.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present twenty-nine Fellows and fourteen guests.

The records of the meeting of December 13 were read and approved.

The Corresponding Secretary announced that the Council had appointed Harlow Shapley as Chairman of the Rumford Committee in place of the late Norton A. Kent.

The President announced that the Boston Institute for Religious and Social Studies will hold meetings at the house of the Academy on eight successive Tuesdays, beginning January 23.

The following communication was presented:

Karl Terzaghi: *Soil Mechanics.*

There was an exhibit of *Some Early New England Refractories used by Paul Revere in his Smelter at Norton, Mass.,* arranged by Professor Frederick H. Norton, of the Massachusetts Institute of Technology.

The meeting was dissolved at 10:15 P. M.

One Thousand and Three Hundredth Meeting

FEBRUARY 14, 1945.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present twenty-three Fellows and eighteen guests.

In the absence of the Recording Secretary his duties were performed by the Corresponding Secretary.

The records of the meeting of January 10 were read and approved.

The following communication was presented:

William Malamud: *A Psychiatric Approach to the Problem of Veteran Readjustment.*

An exhibit of material concerning Massachusetts veterans in former wars was arranged through the courtesy of the Harvard College Library.

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and First Meeting

MARCH 14, 1945.—STATED MEETING

The Academy met at its House at 8:25 P. M.

Vice-President Robinson in the Chair.

There were present forty-two Fellows and eighteen guests.

The records of the meeting of February 14 were read and approved.

It was announced that the President had appointed a Nominating Committee, as follows: Bart J. Bok, of Class I; Frederick K. Morris, of Class II, *Chairman;* Charles E. Wyzanski, Jr., of Class III; Leonard Carmichael, of Class IV.

Announcement was also made of the appointment of a Committee to study the structure and operation of the Academy, in accordance with a vote of the Council last November. This Committee, which has already held two meetings, consists at present of four members: Kirtley F. Mather, *Chairman,* Curt J. Ducasse, John W. M. Bunker, and Leonard Carmichael.

On the recommendation of the Council the following appropriations were voted for the year 1945–1946:

From the income of the General Fund, $7,800, to be used as follows:

for House expenses	$2,600
for General and meeting expenses	1,000
for Library expenses	3,000
for Treasurer's expenses	1,200
Total	$7,800

From the income of the Publication Funds, $2,400, to be used for publication.

From the income of the Rumford Fund, $3,370, to be used at the discretion of the Committee.

From the income of the C. M. Warren Committee, $1,000, to be used at the discretion of the Committee.

The following communication was presented:

Douglas Bush: *The Humanities and Science in Education in the Seventeenth and Twentieth Centuries.*

There was an exhibit of famous Renaissance treatises, loaned by the Houghton Library of Harvard University.

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and Second Meeting

APRIL 11, 1945.—STATED MEETING

The Academy met at its House at 8:27 P. M.

The President in the Chair.

There were present thirty-one Fellows and sixteen guests.

In the absence of the Recording Secretary, his duties were performed by the Corresponding Secretary.

The records of the meeting of March 14 were read and approved.

It was announced that an amendment to the Statutes establishing the Committee on the Permanent Science Fund as a standing committee will be submitted to the Academy for action at its meeting on May 9.

Announcement was made of the proposed Regulations for the Conference of Secretaries of the American Council of Learned Societies. Approval of these regulations will be requested at the next Academy meeting.

The following communication was presented:

Henry Allen Moe: *The Selection of Persons for Research Fellowships.*

The meeting was dissolved at 9:42 P. M.

One Thousand Three Hundred and Third Meeting

MAY 9, 1945.—ANNUAL MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present forty-four Fellows and nine guests.

The records of the meeting of April 11 were read and approved.

The following reports were presented:

REPORT OF THE COUNCIL

Since the last report of the Council there have been reported the deaths of seventeen Fellows: George David Birkhoff, Alexis Carrel, George Whiteley Coggeshall, Alfred Victor de Forest, Edmund Burke Delabarre, Carl Engel, Frederic Harold Fay, James Ford, Philip Fox, Roy Kenneth Hack, William Henry Howell, Walter Louis Jennings, Norton Adams Kent, Charles Francis Park, Robert Hallowell Richards, Frederick Slocum, William Trelease; and nine Foreign Honorary Members: Rt. Hon. James Richard Atkin, Sir Thomas Barlow, Godfrey Rathbone Benson, Baron Charnwood, Gustav Cassel, Sir Arthur Stanley Eddington, Sir William Napier Shaw, Aurel Stodola, Peter B. Struve. Three Fellows have resigned: Melvin Thomas Copeland, William Leonard Crum, Alan Richards Moritz.

Twelve names have been added to the list of Fellows Emeriti: Walter Bradford Cannon, Charles Townsend Copeland, Archibald Thompson Davison, Richmond Laurin Hawkins, Frank Lauren Hitchcock, Reid Hunt, Charles Palache, Walter Raymond Spalding, Clair Elsmere Turner, Alfred North Whitehead, Edmund Allen Whitman, Frederick Shenstone Woods.

Thirty-nine Fellows and four Foreign Honorary Members were elected by the Council and announced to the Academy in May, 1944. All of these have accepted their election with two exceptions—Vera Micheles Dean and Leverett Saltonstall—who declined.

The roll now includes 767 Fellows, 17 Fellows Emeriti, and 113 Foreign Honorary Members (not including those elected in May, 1945).

REPORT OF THE TREASURER

(*Extract*)

In the absence of the Treasurer, his report was read by the Corresponding Secretary. A summary of the receipts and expenditures follows:

*RECEIPTS, 1944–1945

Academy, General:			
From: Investment Income	$13,849.82		
Less: Income to Special Funds	10,972.73		
		$2,877.09	
Assessments and Admission Fees		4,250.00	
			$7,127.09
Amory Prize Committee:			
From: Investment Income			3,352.27
Publications Committee:			
From: Investment Income		$2,303.04	
Sale of Publications		722.39	
Lake Publication, Subscriptions		182.80	
			3,208.23

*Excluding sales of securities.

Rumford Committee:		
From: Investment Income		3,255.41
C. M. Warren Committee:		
From: Investment Income		988.35
Mabel S. Agassiz Fund:		
From: Investment Income		107.40
Permanent Science Fund:		
From: Boston Safe Deposit and Trust Co., Trustee	$10,820.19	
Investment Income	898.23	
		11,718.42
Kennelly Fund:		
From: Investment Income		68.03
Total Receipts		$29,825.20

*EXPENDITURES, 1944–1945

Academy, General:		
Library, Salaries	$2,432.00	
Books and Binding	764.79	
	$3,196.79	
General (Net)	1,062.87	
House (Net)	2,600.13	
Treasurer's Office	599.94	
Insurance	578.25	
		$8,037.98
Amory Prize Committee		
Expense		43.75
Publications Committee:		
General	$604.81	
Lake	13.00	
		617.81
C. M. Warren Committee:		
Grants	$540.00	
Transfer of Income to Fund	1,000.00	
		1,540.00
Mabel S. Agassiz Fund:		
For Meetings		107.40
Permanent Science Fund:		
Grants		2,280.00
Total Expenditures		$12,626.94

REPORT OF THE RUMFORD COMMITTEE

On behalf of the Rumford Fund Committee of the American Academy of Arts and Sciences, I report that during the past year there have been no applications for grants-in-aid received by the Committee.

In view of the current security regulations which prevent our knowing fully of important contributions of the past few years in the fields of heat and light, the Rumford Fund Committee has decided not to recommend candidates for the Rumford Medals.

The Treasurer reports the total funds available for the work of the Committee on March 12, 1945, is $10,113.84, and that the estimated income for 1945–1946 is $3,370.

Respectfully submitted,

HARLOW SHAPLEY, *Chairman*

May 9, 1945

*Excluding purchases of securities.

REPORT OF THE CYRUS M. WARREN COMMITTEE

The Committee had available for grants during the fiscal year 1944–1945 a total sum of $1,669.53, of which $870.00 was appropriated at the March, 1944 meeting and $799.53 remained as a balance from the previous year. It was considered advisable, and so voted by the Committee, to return $1,000.00 to the principal. Grants were made totalling $390.00, as follows:

To Doctor Ralph N. Prince of the University of New Hampshire, a grant of $200.00 for materials to construct apparatus in connection with a project to develop an optical means of determining the purity of cellulosic materials.

To Professor Pierre Van Rysselberghe of the University of Oregon, a grant of $190.00 for the purchase of a Leeds and Northrup audio frequency oscillator for use in the dertermination of the conductances of non-aqueous solutions of metallic salts, particularly those of magnesium and aluminum.

A further report was received from Professor Thomas W. Davis of New York University in regard to his grant of the preceding year. After considerable delay he was able to secure a suitable fractionating column for which the grant was awarded.

Respectfully submitted,

FREDERICK G. KEYES, *Chairman*

May 9, 1945

REPORT OF THE COMMITTEE OF PUBLICATION

The Publication Committee has held no regular meetings this year, business having been transacted by consultation and correspondence. Three numbers of the *Proceedings* have been published:

VOLUME 75

5. Barnett, S. J. *New Researches on Magnetization by Rotation and the Gyromagnetic Ratios of Ferromagnetic Substances.* pp. 109–129. August, 1944.

6. *Presidential Address; Records of Meetings; Biographical Notices; Presidents of the Academy; Officers and Committees; List of Fellows and Foreign Honorary Members, etc.;* pp. 131–208. December, 1944.

VOLUME 76

1. Bridgman, P. W. *The Compression of Twenty-one Halogen Compounds and Eleven Other Simple Substances to 100,000 kg/cm²; the Compression of Sixty-one Solid Substances to 25,000 kg/cm², Determined by a New Rapid Method.* pp. 1–24. February, 1945.

The Index to Professor and Mrs. Lake's *Dated Greek Minuscule Manuscripts to the year 1200* has been en-

tirely printed off and is being bound. It forms a monograph of smaller format than the plates—about 200 pages. It seemed wise to print a larger number of these as there will be individual sales for it in addition to those to subscribers to the series.

Professor Hatch's *Dated Syriac Manuscripts* is in corrected page proof, but has not, at last reports, been printed off. There are no other papers on the roster for publication.

Respectfully submitted,
ROBERT P. BLAKE, *Chairman*

May 9, 1945

REPORT OF THE LIBRARY COMMITTEE

During the year, 111 bound volumes (mainly of serials) were added to the library, making a total of 47,372 now on the shelves. Of this number 97 were received by gift or exchange and 14, or only 8 per cent, were purchased. The appropriation was $2,625 for the year ending March 31, 1945. Expenditures were as follows:

Salaries	$2,432.00
Purchase of books and periodicals	522.54
Binding and repairing	242.25
Total	$3,196.79

In addition to the use of books in the building, 57 books and pamphlets were borrowed by 5 Fellows and 19 libraries.

Thus reads, in general, the gist of annual reports varying little within the present century, in the earlier years of which the Academy ceased adding to its book collection, concentrated upon its periodical files—and made almost negligible use of either. Yet the library, a terra incognita to most of our Fellows, has been in a sense the integrating symbol of the Academy as generations have passed. Our shelves still hold the books of eighteenth-century founders; and accessions of the nineteenth-century form a unique record of the scientific and humanistic interests of the Academy throughout that period. Since then, the principal growth has been in periodical files, so that now the stacks groan with memoirs and transactions from every intellectual quarter of the globe.

A recent inspection of the shelves kindly undertaken by a group of expert librarians has emphasized the potential value of our unexploited resources. At the same time the opinion was expressed that these resources can be made useful only in so far as they are selectively dispersed to areas which lack, rather than duplicate the material. Your Committee are not in sufficient agreement to render concerted opinion; but the facts should be understood by all.

To our great misfortune, the extent of appropriation and personnel allotted to the upkeep of the collection has for many years been insufficient to cope with a growth which now nears the 50,000-volume mark. The library has had throughout not only to shoulder the highly detailed work of the general secretariat, but to carry it under the library appropriation. This means that there can be no strictly full-time staff service, and no provision for the conservation of library property except through part-time janitorial effort. It means above all an undue demand upon the Assistant Librarian, whose executive duties greatly limit the exercise of her technical library training and experience.

The librarian of an earlier generation, in reporting the inability of one person to handle both library and general Academy business, took occasion to note the "crumbling away" of the old bindings. Seven years later, in 1913, his successor estimated that, in the new building, overcrowding was provided against for fifteen years. Now, after thirty years' growth, the congestion is deplorable and "crumbling" unabated; with no relief in sight other than drastic dismemberment applied to all but historic treasures, the salvage of which is already proving a long and expensive process.

Hence from more than one direction we are impelled toward some form of radical action. Nevertheless, to those who know our library it has a strong utilitarian as well as antiquarian appeal. To these it continues to prove an invaluable resource, containing as it does many long and rare files and offering to Fellows certain privileges of withdrawal unapproached in their liberality. Your Committee invite examination of the stacks and urge full consideration of the situation. It is one of the major problems now before us.

Respectfully submitted,
FREDERICK H. PRATT, *Chairman*

May 9, 1945

REPORT OF THE HOUSE COMMITTEE

During the year ending March 31, 1945, the House Committee has had at its disposal funds amounting to $2,852.69, as follows:

Appropriation for 1944–1945	$2,600.00
Received from other societies for the use of House facilities	252.69
Total	$2,852.69

The expenditures amounted to $2,852.92. Of this sum $2,699.83 was spent for the routine expenses, janitor, heat, light, telephone, etc., and $153.09 for the upkeep of the building.

Meetings have been held as follows:

The Academy	8
American Council of Learned Societies	3
Archaeological Institute of America, Boston Chapter	1
Boston Surgical Society	3
Institute for Religious and Social Studies	8
New England Botanical Club	9
Pan-American Society of Massachusetts	10
United China Relief	4
Total	46

The Council Chamber has been used for the Academy Council and Committee meetings, and also by the

Trustees of the Children's Museum and the New England Farm and Garden Association.

A detailed list of the expenditures follows:

Janitor	$1,001.00
Fuel	1,013.58
Electricity: Light	197.73
Power	46.28
Elevator service and repairs	134.24
Telephone	155.96
Gas	54.90
Water	64.40
Upkeep of building	153.09
Janitor's supplies and sundries	31.74
Total	$2,852.92

The Academy received during the year by gift from Mrs. Maximilian Agassiz portraits of Louis, Alexander, and Maximilian Agassiz, and a bronze bas-relief of Alexander Agassiz together with a copper plate inscribed with resolutions passed in his memory by the stockholders of the Calumet & Hecla Consolidated Copper Co. These have been hung in the rooms of the Academy. A letter of thanks was sent to Mrs. Agassiz by the Chairman of the House Committee.

Respectfully submitted,

C. M. SPOFFORD, *Chairman*

May 9, 1945

The Corresponding Secretary announced that the following had been elected members of the Academy:

FELLOWS

CLASS I, SECTION 1

Garrett Birkhoff ..... Cambridge
Norman Levinson ..... Belmont

CLASS I, SECTION 2

Robley Dunglison Evans ..... Belmont

CLASS I, SECTION 3

Eric Glendinning Ball ..... Newton Highlands
Arthur Clay Cope ..... Belmont
John Lawrence Oncley ..... Watertown

CLASS I, SECTION 4

Hardy Cross ..... New Haven, Conn.
Frederick Emmons Terman ..... Belmont
John Benson Wilbur ..... Belmont

CLASS II, SECTION 1

Martin Julian Buerger ..... Lincoln
Henry Crosby Stetson ..... Belmont

CLASS II, SECTION 2

Dennis Robert Hoagland ..... Berkeley, Calif.
Herman Augustus Spoehr ..... Palo Alto, Calif.

CLASS II, SECTION 3

John Robert Loofbourow ..... Cambridge
John Henry Welsh, Jr. ..... Cambridge
Leland Clifton Wyman ..... Jamaica Plain

CLASS II, SECTION 4

James Morison Faulkner ..... Brookline
Thomas Hale Ham ..... Brookline

CLASS III, SECTION 3

Seymour Edwin Harris ..... West Acton
William Rupert Maclaurin ..... Cambridge
Talcott Parsons ..... Belmont
Howard Eugene Wilson ..... West Newton

CLASS III, SECTION 4

Edwin Sharp Burdell ..... New York, N. Y.
William Lockhart Clayton ..... Washington, D. C.
Henry Allen Moe ..... New York, N. Y.

CLASS IV, SECTION 1

Edwin Ray Guthrie ..... Seattle, Wash.
Charles Lincoln Taylor, Jr. ..... Cambridge

CLASS IV, SECTION 3

George Wiley Sherburn ..... Cambridge
Taylor Starck ..... Cambridge

CLASS IV, SECTION 4

Samuel Chamberlain ..... Marblehead
William Alexander Jackson ..... Cambridge
Keyes DeWitt Metcalf ..... Belmont
Martin Wagner ..... Cambridge

FOREIGN HONORARY MEMBERS

CLASS I, SECTION 1

Sir Harold Spencer Jones ..... Greenwich

CLASS I, SECTION 2

Niels David Bohr ..... Copenhagen

CLASS III, SECTION 3

Dennis Holme Robertson ..... London

CLASS III, SECTION 4

Alfredo L. Palacios ..... Buenos Aires

CLASS IV, SECTION 3

Tomás Navarro Tomás ..... Madrid

It was voted to adopt an amendment to the Statutes by inserting in Chapter XI in Article 2 the following paragraph:

The Permanent Science Fund Committee, to consist of seven Fellows, which shall recommend from time to time to the Council all appropriations from the income received by the Academy from the Trustee of the Permanent Science Fund, for effecting the purposes set forth in the Agreement and Declaration of Trust which governs the use of this Fund.

It was voted to approve amendments to the constitution and by-laws of the American Council of Learned Societies, providing for a conference of secretaries at the annual meeting of the Council.

On the recommendation of the Treasurer it was voted that the annual assessment for resident Fellows for the year 1945–1946 be fifteen dollars.

The annual election resulted in the choice of the following officers and committees:

Howard M. Jones ..... *President*
George R. Harrison ..... *Vice-President for Class I*
Alfred C. Lane ..... *Vice-President for Class II*
Ralph E. Flanders ..... *Vice-President for Class III*
Fred N. Robinson ..... *Vice-President for Class IV*
Abbott P. Usher ..... *Corresponding Secretary*
Hudson Hoagland ..... *Recording Secretary*
Horace S. Ford ..... *Treasurer*
Frederick H. Pratt ..... *Librarian*
Robert P. Blake ..... *Editor*

COUNCILLORS FOR FOUR YEARS

John H. Van Vleck ..... Class I
Charles H. Blake ..... Class II
Oliver M. W. Sprague ..... Class III
Harry A. Wolfson ..... Class IV

COMMITTEE ON POLICY AND RESOURCES

For Five Years: W. Cameron Forbes

FINANCE COMMITTEE

Jerome C. Hunsaker — Henry P. Kendall
Ralph E. Freeman — John F. Ebersole

RUMFORD COMMITTEE

Harlow Shapley, *Chairman*

Percey W. Bridgman — Robert B. Lindsay
Harry M. Goodwin — Francis O. Schmitt
George R. Harrison — Edwin H. Land

C. M. WARREN COMMITTEE

Frederick G. Keyes, *Chairman*

Gregory P. Baxter — Avery A. Morton
Charles A. Kraus — Walter C. Schumb
Grinnell Jones — Kenneth L. Mark

COMMITTEE OF PUBLICATION

Robert P. Blake, *Chairman, ex officio*

Edwin C. Kemble ..... Class I
Ralph H. Wetmore ..... Class II
Arthur H. Cole, ... Class III
Robert P. Casey ..... Class IV

COMMITTEE ON THE LIBRARY

Frederick H. Pratt, *Chairman, ex officio*

Raymond C. Archibald ..... Class I
Thomas Barbour ..... Class II
Francis N. Balch ..... Class III
Henry B. Washburn ..... Class IV

AUDITING COMMITTEE

Erwin H. Schell — Alexander Forbes

HOUSE COMMITTEE

Charles M. Spofford, *Chairman*

H. Addington Bruce — Robert P. Bigelow
Donald S. Tucker

COMMITTEE ON BIOGRAPHICAL NOTICES

For Three Years

Alfred C. Lane — Austin W. Scott

COMMITTEE ON MEETINGS

The President
The Recording Secretary

Leonard Carmichael — Jerome D. Greene
Abbot P. Usher — Frederick K. Morris

The following communication was presented:

Joseph P. Hudnut and Carl J. Friedrich: *The Boston Contest.*

The meeting was dissolved at 10:20 P. M.

One Thousand Three Hundred and Fourth Meeting

OCTOBER 10, 1945.—STATED MEETING

The Academy met at the Old South Parish House Building, in Copley Square, at 8:15 P. M., the change of meeting place having been made necessary by repairs to the house of the Academy.

This meeting had been designated as Ladies' Night, and there were present about three hundred Fellows and guests.

The reading of the records of the meeting of May 9 was omitted.

The following communication was presented:

Harlow Shapley: *Report on Soviet Science.*

The meeting was then dissolved.

One Thousand Three Hundred and Fifth Meeting

NOVEMBER 14, 1945.—STATED MEETING

The Academy met at the Old South Parish House Building at 8:22 P. M.

The President in the Chair.

There were present fifty-one Fellows and twenty guests.

The records of the meetings of May 9 and October 10 were read and approved.

It was voted to discontinue the Committee on Policy and Resources (a standing committee), through an amendment to the Statutes, deleting Paragraph ii, Article 2, of Chapter XI.

Professor Robley D. Evans was presented to the Academy by Vice-President George R. Harrison.

The Chairman of the House Committee reported on the progress of the plans for the alteration of the Academy's House.

The President announced that the four Vice-Presidents had been asked to prepare lists of the war work of the Fellows in their Classes, and gave a brief review of the partial returns reported by three of them.

The topic for the evening was *A National Policy for Scientific Research* and it was presented as a symposium by Messrs. Bradley Dewey, Pendleton Herring and Lee A. Du Bridge. The communications were followed by a lively discussion from the floor.

The meeting was dissolved at 10:15 P. M.

One Thousand Three Hundred and Sixth Meeting

DECEMBER 12, 1945.—STATED MEETING

The Academy met at the Old South Parish House Building at 8:25 P. M.

The President in the Chair.

There were present thirty-seven Fellows and fourteen guests.

In the absence of the Recording Secretary, the Corresponding Secretary read the records of the meeting of November 14, which were approved by the Academy.

The Corresponding Secretary reported that the Council had prepared a number of amendments to the Statutes designed to clarify the language of several paragraphs, to define more adequately the powers and duties of the President, and to describe the procedure on amendments that has in fact been followed since the establishment of the Council.

The following communication was presented:

Charles E. Wyzanski, Jr.: *The War Criminal Trials.*

After a stimulating discussion, the meeting was dissolved at 10 P. M.

One Thousand Three Hundred and Seventh Meeting

JANUARY 9, 1946.—STATED MEETING

The Academy met at the Old South Parish House Building at 8:20 P. M.

The President in the Chair.

There were present eighty-four Fellows and thirty-four guests.

The records of the meeting of December 12 were read and approved.

In the absence of the Corresponding Secretary, the Recording Secretary announced that the Council had adopted the following resolution:

Believing that the peace of the world and the advancement of the arts, the sciences, and education in all countries can be effectively furthered by an active support of the United Nations Educational, Scientific and Cultural Organization, the Council of the American Academy of Arts and Sciences congratulates the Senate and House of Representatives of the Congress of the United States upon the several resolutions adopted by them favoring support of this organization, and urges upon the Congress the desirability of ratifying the charter of the organization on the basis of the signature of our representatives at the London Conference last November.

In order that the widest support may be given to the United Nations Educational, Scientific and Cultural Organization, the Council desires that copies of this resolution shall be sent to all the learned and scientific bodies throughout the world with which it has communication, to the public press, to the President of the United States, the Secretary of State, the Speaker of the House, the President of the Senate, and the Assistant Secretaries of State.

The President announced that instead of the usual stated meeting in April, the Academy would hold a dinner meeting at the Copley Plaza Hotel on April 17.

The following communication was presented:

James Bryant Conant: *Science and the National Welfare.*

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and Eighth Meeting

FEBRUARY 13, 1946.—STATED MEETING

The Academy met at the Old South Parish House Building at 8:20 P. M.

The President in the Chair.

There were present thirty-five Fellows and four guests.

In the absence of the Recording Secretary, the Corresponding Secretary served in his stead.

The records of the meeting of January 9 were read and approved.

Two new Fellows were introduced: William A. Jackson by Vice-President Robinson, and Talcott Parsons by the Corresponding Secretary.

The following amendments to the Statutes recommended by the Council at its January meeting were adopted by the Academy with no dissenting votes:

CHAPTER II, Article 4, shall be amended to read: "If any person, after being notified of his election as Fellow, shall neglect for six months to accept in writing, or if a Fellow resident within fifty miles of Boston shall neglect to pay his Admission Fee *within six months* of his election, his election shall be void; and if any

Fellow resident within fifty miles of Boston shall neglect to pay his Annual Dues for six months after they are due, provided his attention shall have been called to this Article of the Statutes *by the Treasurer* in the meantime, he shall cease to be a Fellow.

A non-resident Fellow, elected since 1938, who neglects to pay his Annual Dues for six months after they are due, and who ignores notification by the Treasurer of the requirement of this Article, shall cease to be a Fellow.

But upon petition by the Fellow or by any officer of the Academy, the Council may by a majority vote suspend the provisions of this Article for any additional period of time not longer than three months."

CHAPTER II, Article 5. First paragraph: Omit the clause: "unless previously as an Associate he has paid an Admission Fee of like amount." Second paragraph, second line: Omit the words "and others may."

CHAPTER IV, Article 1. Paragraph three, third line: Omit "on Resources and Policy" and substitute "on the Permanent Science Fund."

CHAPTER V, Article 1. For "the senior" in the second line, substitute "a." Omit the parenthesis ("seniority to be determined by length of continuous fellowship in the Academy").

Add as a new paragraph:

"The President shall be the chief executive officer of the Academy. He shall present to the Council for its consideration all matters pertinent to the interests of the Academy and to the discharge of its obligations to the community or to the advancement of scholarship. The President shall be Chairman of the Committee on Meetings."

CHAPTER VI, Article 1. Add a paragraph as follows:

"He shall arrange for the preservation of records of the death of Fellows and biographical notices published on the occasion of their death, or at other times. If existing notices are inadequate, he shall arrange for the preparation of a suitable biographical notice to be published in the Proceedings of the Academy or in some professional journal associated with the activities of the deceased Fellow."

CHAPTER VI, Article 2. Last paragraph, first line, substitute "any" for the second "the."

CHAPTER XI. Omit paragraph (ii) as it now stands and substitute the paragraph providing for a standing committee on the Permanent Science Fund, Omit paragraph (x).

CHAPTER XII, Article 7. Omit the present text and substitute the following:

"All amendments to the Statutes, whether proposed by Fellows or by the Council, shall be considered by the Council and reported with recommendations for action to the Academy. At a subsequent Stated Meeting, or at a Special Meeting called for the purpose, the notice for which in either case shall state this proposed amendment, the Academy shall act upon the amendment. Two-thirds of the Fellows present, in a meeting of not less than twenty-five Fellows, must vote in the affirmative to enact the amendment."

The following communication was presented:

Edward Sagendorph Mason: *The Economic Future of Germany.*

The meeting was dissolved at 9:40 P. M.

One Thousand Three Hundred and Ninth Meeting

MARCH 13, 1946.—STATED MEETING

The Academy met at its House at 8:25 P. M.

The President in the Chair.

There were present forty Fellows and six guests.

The records of the meeting of February 13 were read and approved.

On the recommendation of the Council the following appropriations for the year 1946–1947 were voted:

From the income of the General Fund, $9,200, to be used as follows:

For House expenses	$3,600
for General and Meeting expenses	1,400
for Library expenses: Salaries	2,400
Books, Periodicals & Binding	600
for Treasurer's expenses	1,200
Total	$9,200

It was also voted that the Editor, the Chairman of the Rumford Committee, and the Chairman of the C. M. Warren Committee be authorized to draw upon the balances available in their respective Funds.

The President announced that he had appointed the following as a Nominating Committee: Bart J. Bok, of Class I, *Chairman;* Ralph H. Wetmore, of Class II; Douglass V. Brown, of Class III; Michael J. Ahern, S. J., of Class IV.

The following communication was presented:

Kenneth V. Thimann: *Growth Hormones in Plants.* This was illustrated by lantern slides and by living material.

The meeting was dissolved at 9:30 P. M.

One Thousand Three Hundred and Tenth Meeting

APRIL 17, 1946.—DINNER MEETING

The first annual dinner meeting of the Academy was held at the Copley Plaza Hotel on Wednesday, April 17, taking the place of the stated meeting on April 10.

One hundred and sixteen members were present, and the speakers were Dr. Waldo G. Leland, of the American Council of Learned Societies, and President Karl T. Compton, of the Massachusetts Institute of Technology.

At the request of the President, Mr. Robert Frost recited several of his poems.

One Thousand Three Hundred and Eleventh Meeting

MAY 8, 1946.—ANNUAL MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present fifty-eight Fellows and eleven guests.

The records of the meetings of March 13 and April 17 were read and approved.

The Corresponding Secretary reported that the Council had voted to recommend to the Academy that the Statutes be amended to provide for the addition of the Amory Prize Committee to the list of standing committees.

He also read a resolution which the Council had adopted, copies of which are to be sent to the President of the United States, the President of the Senate, the Speaker of the House, the Senators from the Commonwealth of Massachusetts, and other academies in the United States of America, as follows:

WHEREAS, whole populations in Europe and Asia face death by hunger if immediate and extensive help is not given them; and

WHEREAS, the loss to the world by starvation of scientists and scholars is of special concern to learned bodies; and

IN SO FAR as the food sent abroad from this country is neither in proportion to what we can spare nor adequate to the crisis,

Resolved, by the Council of the American Academy of Arts and Sciences, that we urge upon our government an increase in the amount of wheat, milk, and fats set aside to meet this emergency as well as an increase in the amount and speed of the transportation accorded this food; and

Resolved, that, voluntary rationing having proved inadequate, we urge a return to consumer rationing to assure both fair distribution of food in this country and adequate supplies for famine relief; and

Resolved, that copies of this resolution be sent to the President of the United States, the President of the Senate, the Speaker of the House, the Senators from the Commonwealth of Massachusetts, and other academies in the United States of America.

The Corresponding Secretary announced that at its meeting on April 30 the Council had made the following grants from the Permanent Science Fund:

1. To Charles F. Brooks, Director, Blue Hill Observatory, Harvard University, for completion of certain studies of cloud systems associated with storms in the eastern United States, $625.

2. To Gregory Pincus, Director of Laboratories, Worcester Foundation for Experimental Biology, for assistance in a study of hormonal control of lymphocytes, $1,800.

3. To A. H. Reesor Smith, Lecturer, College of Engineering, University of California, as compensation for assistance contingent upon remaining necessary funds being secured otherwise for the synthesis of vinyl cyclopropane, $1,800.

4. To George Sachs, Professor of Physical Metallurgy, Case School of Applied Science, Cleveland, as compensation for assistance in the study of properties of thin metallic membranes, $900.

5. To Irving M. Klotz, Instructor in Chemistry, Northwestern University, for assistance in his study of the interactions of proteins with organic molecules, $1,300.

The Corresponding Secretary announced that the following had been elected members of the Academy:

FELLOWS

CLASS I, SECTION 1.

James Gilbert Baker ..... Waban
John Landes Barnes ..... Winchester
Subrahmanyan Chandrasekhar .... Williams Bay, Wis.

CLASS I, SECTION 2

Lee Alvin Du Bridge ..... Rochester, N. Y.
Julius Adams Stratton ..... Belmont

CLASS I, SECTION 3

Paul Doughty Bartlett ..... Weston
Walter Hugo Stockmayer ..... Weston

CLASS I, SECTION 4

William Loren Batt ..... Washington, D. C
Howard Wilson Emmons ..... Sudbury

CLASS II, SECTION 1

Roland Frank Beers ..... Lincoln
Cornelius Searle Hurlbut, Jr. ..... Belmont

CLASS II, SECTION 2

Ralph Erskine Cleland ..... Bloomington, Ind.

CLASS II, SECTION 3

George Wells Beadle ..... Palo Alto, Calif.
James Lee Peters ..... Harvard
Kenneth David Roeder ..... Medford

CLASS II, SECTION 4

John Franklin Enders.....Boston
Charles Alderson Janeway.....Weston
Siegfried Josef Thannhauser.....Brookline

CLASS III, SECTION 2

Harvey Hollister Bundy.....Boston
John Sloan Dickey.....Hanover, N. H.
Robert Burgess Stewart.....Winchester

CLASS III, SECTION 3

Theodore Henry Brown.....Cambridge
Harold Walter Stoke.....Durham, N. H.

CLASS III, SECTION 4

Chester M. Alter.....West Newton
David Frank Edwards.....Cambridge
Huntley Nowell Spaulding.....Rochester, N. H.

CLASS IV, SECTION 1

Brand Blanshard.....New Haven, Conn.
Stanley Smith Stevens.....Cambridge

CLASS IV, SECTION 2

Clarence Saunders Brigham.....Worcester
Paul Herman Buck.....Cambridge
Otto Eduard Neugebauer.....Providence, R. I.

CLASS IV, SECTION 3

George Raleigh Coffman.....Chapel Hill, N. C.
John Huston Finley, Jr.....Cambridge

CLASS IV, SECTION 4

Edward Weeks, Jr.....Boston
William Wilson Wurster.....Boston

FOREIGN HONORARY MEMBERS

CLASS I, SECTION 1

Bertil Lindblad.....Stockholm
Jan Hendrik Oort.....Leiden

CLASS I, SECTION 4

Clarence Decatur Howe.....Ottawa

CLASS II, SECTION 2

Rudolf Florin.....Stockholm

CLASS III, SECTION 2

Winston Churchill.....London

CLASS IV, SECTION 1

Francisco Romero.....Buenos Aires

CLASS IV, SECTION 4

William George Constable.....Cambridge, Mass.

The following reports were then presented to the Academy:

REPORT OF THE COUNCIL

Since the last report of the Council there have been reported the deaths of twenty-six Fellows and Fellows Emeriti: Thomas Barbour, Carl Lotus Becker, Edward Wilber Berry, William Crowell Bray, Walter Bradford Cannon, Charles Jay Connick, John Franklin Ebersole, Max Farrand, Simon Flexner, Edwin Francis Gay, Edwin Walter Kemmerer, Gilbert Newton Lewis, Leo Rich Lewis, John Livingston Lowes, Albert Matthews, John Campbell Merriam, Roger Bigelow Merriman, Thomas Hunt Morgan, William Allan Neilson, William Abbott Oldfather, William Morton Prest, Edward Kennard Rand, Theodore Leslie Shear, Carl Snyder, Harlan Fiske Stone, Jacob David Tamarkin; and two Foreign Honorary Members: Ludwig Diels, and John Maynard Keynes. Three Fellows have resigned: Frederic Adrian Delano, Wassily W. Leontief, and Edward Sagendorph Mason; and the Fellowship of Manley Ottmer Hudson has been discontinued.

Ten names have been added to the list of Fellows Emeriti: Charles Thomas Brues, George Henry Chase, William Scott Ferguson, Henry Thatcher Fowler, William Hovgaard, Edward Felix Langley, Samuel Cate Prescott, Percy Edward Raymond, La Rue Van Hook, George Benson Weston.

Thirty-three Fellows and five Foreign Honorary Members were elected by the Council and announced to Academy in May, 1945. All but William Lockhart Clayton and Howard Eugene Wilson accepted election.

Not including those elected in 1946, the roll now includes 764 Fellows and 116 Foreign Honorary Members as well as 23 Fellows Emeriti.

REPORT OF THE TREASURER

(*Extract*)

*RECEIPTS, 1945–1946

Academy, General:		
Investment Income	$16,295.46	
Less: Income to Special Funds	13,214.13	
	$3,081.33	
Assessments and Admission Fees	6,208.75	
		$9,290.08
Mabel S. Agassiz Fund:		
Investment Income		116.70
Amory Prize Committee:		
Investment Income		3,839.43
Kennelly Fund:		
Investment Income		77.90
Life Membership Fund:		
Robley D. Evans		200.00
Permanent Science Fund:		
Boston Safe Deposit and Trust Co., Trustee	$11,436.40	
Investment Income	1,517.10	
		12,953.50
Publications Committee:		
Investment Income	$2,800.80	
Sale of Publications	513.81	
		3,314.61

* Excluding sales of securities.

Rumford Committee:		
Investment Income	$3,788.27	
Return of Grant	188.91	
		3,977.18
Special Expense Fund:		
American Council of Learned Societies		1,000.00
Special Alterations Fund:		
Contributions		760.00
C. M. Warren Committee:		
Investment Income	$1,073.93	
Return of Grant	200.00	
		1,273.93
Total Receipts		$36,803.33

*EXPENDITURES, 1945–1946

Academy, General:			
Library, Salaries	$2,228.00		
Books & Binding	632.38		
		$2,860.38	
General (Net)		1,416.41	
House (Net)		3,695.83	
Treasurer's Office		722.19	
Insurance	$1,445.84		
Less Unexpired Premiums	916.18	529.66	
			$9,224.47
Mabel S. Agassiz Fund:			
For Meetings			116.70
Amory Prize Committee			
Expense			38.90
Permanent Science Fund:			
Grants		$900.00	
Expense		103.95	
			1,003.95
President's Special Expense Account:			
Expense			55.00
Publications Committee:			
General		$1,381.62	
Lake		1,838.65	
			3,220.27
Rumford Committee:			
Grant		$250.00	
Rumford Memorial		25.25	
			275.25
Special Expense Fund			62.71
Special Alterations Fund			3,867.22
Warren Fund Committee:			
Grants			505.00
Total Expenditures			$18,369.47

REPORT OF THE RUMFORD COMMITTEE

I have the report from the Treasurer which indicates that we have on hand a balance of $13,832.50, and that we have an estimated income for next year of about $3,800.

Contribution to the present considerable balance comes from returns of earlier grants to the amount of $730. During the past year we made but a single expenditure: $275.25.

By general agreement we gave no Rumford medals this year on the grounds that we needed a little perspective with respect to the important wartime contributions before we next selected a man to honor.

Respectfully submitted,

HARLOW SHAPLEY, *Chairman*

May 8, 1946.

REPORT OF THE CYRUS M. WARREN COMMITTEE

The Committee had available for grants during the fiacal year 1945–1946 the sum of $1,000 which was appropriated at the March, 1945 meeting.

The following grants were made after consideration of the applications submitted to the Committee:

To Professor Hugh J. McDonald of the Illinois Institute of Technology, a grant of $205, for the purchase of a Beckman pH Meter to be used in connection with a study of the kinetics of dissolution of metals in various aqueous solutions.

To Professor Pierre Van Rysselberghe of the University of Oregon, a grant of $300, to apply on the purchase of a Beckman Ultraviolet Spectrophotometer for use in the polarographic reduction of chlorophyll.

A report was received from Mr. Ralph N. Prince Textile Research Fellow, at the University of New Hampshire, in regard to a grant of $200 awarded in 1944. In a letter dated July 17, 1945, Mr. Prince stated:

"Although considerable preliminary work was done during the year, the press of other matters was so great, that no real progress was made on the proposed project. A short report had been prepared for submission in May; however, at that time it was apparent that the work could not be continued in the near future. Therefore the matter was held up until the exact situation could be determined.

"It has developed that I shall not be located here at the Engineering Experiment Station after August 1st, and there will be little opportunity for me to continue the project in the near future.

"Therefore, I have asked that the entire amount of the grant be returned to you. I am attaching a copy of the preliminary report in addition to the check."

Respectively submitted,

FREDERICK G. KEYES, *Chairman*

May 8, 1946

REPORT OF THE COMMITTEE OF PUBLICATION

No meeting of the Publication Committee was held during the year, such business as came up having been conducted by correspondence.

The Index to Professor and Mrs. Lake's *Dated Greek Manuscripts* was published during the year.

* Excluding purchases of securities.

This covers the ten fasciculi which have been published. If a supplementary fascicule should appear later, this will be separately indexed.

Professor Hatch's *Album of Dated Syriac Manuscripts* is in the press.

No new numbers of the *Proceedings* or of the *Memoirs* were published, but a manuscript by President Howard Mumford Jones has been accepted on the literature of colonial Virginia in the 17th century. It is now being composed, and will be included in the *Memoirs*.

Respectfully submitted,

ROBERT P. BLAKE, *Chairman*

May 8, 1946

REPORT OF THE LIBRARY COMMITTEE

During the year 86 bound volumes were added to the library, making a total of 47,458 now on the shelves; of this number 79 were received by gift or exchange, and seven were purchased.

In addition to the use of books in the building, 63 books and pamphlets were borrowed by 7 Fellows and 21 libraries.

The appropriation for the year ending March 31, 1946, was $3,000, and the expenditures were as follows:

Salaries	$2,228.00
Purchase of books and periodicals	450.43
Binding and repairing	181.95
Total	$2,860.38

No way has been found to mitigate the conditions of congestion, under-staffing and meagre use of our library pointed out in last year's report; and, in view of the accompanying severe deterioration of the building, the council has delegated a special committee to arrange the sale of our main stock of books and periodicals. The economy resulting from cancellation of subscriptions and the assets potential in our extremely valuable holdings have meanwhile enabled the Building Committee to proceed without delay in its arduous work of rehabilitation.

Meanwhile, we have devoted our attention to the following two operations:

1. The identification and segregation of such early acquisitions as may properly be added to the archives of the Academy—chiefly the several hundred volumes of the Governor Bowdoin bequest. To these are added books associated with the Founders and other distinguished early Fellows of the Academy, making a discrete collection of about 1000 volumes, the ultimate housing of which must depend upon what can be done to give them worthy protection and care. We have had the valuable assistance of Mrs. Anne Smith in the arrangement of this collection.

2. The Librarian is by statute the custodian and distributor of the Academy's publications. These have of necessity accumulated unduly during the war, and we have been fortunate in securing the expert services of Mr. Richard Hoffman in sorting, packaging and packing for shipment the various consignments to the many exchanging and subscribing institutions here and abroad. Your Committee have discussed at length, but tentatively, policies concerning publication and exchange that impending conditions must determine. The likelihood of a new and wide demand on our store of past *Transactions* and *Memoirs* makes early attention to these holdings imperative.

That Mr. Metcalf, Mr. Osborne and members of the Widener Library staff have shouldered the entire administrative and executive burden of checking the main collection of books, serials, and pamphlets, has alone made it possible for us to carry out the above programs.

During the exceedingly trying conditions that have necessarily attended building repairs and alterations, the Assistant Librarian has continued the Academy's business without intermission; and we cannot but deeply appreciate Mrs. Ball's persevering attention to the many and various demands of her office.

Respectfully submitted,

FREDERICK HAVEN PRATT, *Chairman*

May 8, 1946

REPORT OF THE HOUSE COMMITTEE

During the year ending March 31, 1946, the House Committee faced a number of unusual difficulties. These included the voluntary resignation of Thomas H. Gately who had held the position of janitor for twenty-six years, and the engagement of Thomas Redgate for this position. Mr. Gately was voted a monthly pension of $50 in view of his faithful service, and he was a guest of the Council at one of its dinner meetings.

A large number of repairs were required by the recently enacted city safety regulations. Moreover certain portions of the rear wall fell without warning, fortunately without injuring anyone, and had to be replaced; and certain other unusual repairs were necessary including the cleaning and waterproofing of the elevator pit, the installation of new grates in the furnace, and repairs to the elevator. The costs of some of these are being met by special funds and do not all appear in the expenditures listed below. In addition to the necessary repairs, the Academy has improved the building by redecorating the interior and by removing the book stacks from the entrance lobby. It has also installed alternating current electric power in order to provide an emergency lighting system.

Receipts from other societies using the building were materially reduced by the fact that the building was not available for many meetings on account of the repairs being made.

As a result of the repairs and decorating, and because one of its regular meetings was replaced by a dinner meeting at the Copley Plaza Hotel, the Academy has held only two of its regular monthly meetings in its House. The other regular meetings of the Academy were held in the Mary Norton Hall of the Old South Parish House at the corner of Boylston and Dart-

mouth Streets. The other societies holding meetings at the Academy building were: the New England Botanical Club, which held eight meetings in the Reading Room; the Boston Mineral Club, one meeting.

The appropriation for House expenses for the year ending March 31, 1946, was $2,600, and during that period $180 was received from other societies for the use of facilities, making a total of $2,780, which was materially exceeded as a consequence of the foregoing unforeseen expenses.

A detailed list of expenditures follows:

Janitor	$1,136.13
Fuel	1,197.02
Electricity: Light	278.30
Power	47.85
Elevator service and repairs	292.09
Telephone	146.85
Gas	42.24
Water	53.36
Upkeep	353.29
Janitor's supplies and sundries	81.70
Thomas H. Gately's pension	250.00
Total	$3,878.83

Respectfully submitted,
CHARLES M. SPOFFORD, *Chairman*

REPORT OF THE COMMITTEE ON THE PERMANENT SCIENCE FUND

The Committee on the Permanent Science Fund, appointed as a special committee by the Council on December 12, 1928, and yearly thereafter, has held semi-annual meetings without interruption since that date. In May, 1945, by vote of the Council the probable permanency of this committee was recognized, and it was made a Standing Committee of the Academy. For the year 1945–1946 its personnel continued in ad hoc status pending the 1946 election of officers and committees.

During the twelve months since May, 1945, the Committee has considered seventeen applications, of which five were recommended to and approved by the Council for grants-in-aid totalling $6,425.00.

The devotion of efforts of scientists to the prosecution of the war has reduced the volume of applications for aid addressed to this Committee to one in October, 1945, a circumstance which is unique in its seventeen years of continuous experience.

Notices of the nature and availability of the Permanent Science Fund were thereupon furnished to the editors of 28 journals representing a wide coverage of natural, social and mathematical sciences, in the United States, Canada and Britain.

The Permanent Science Fund endowment was reported by its Trustee to amount to about $315,000 in 1944. Income from this fund is paid semi-annually to the Academy, designated in the Indenture of Trust as the disbursing agent therefor. Accumulated income is invested by our own Treasurer and its earnings added to its accumulations, which as of March 31, 1946, are of the order of $47,000, of which the last yearly increment received from the Trustee was slightly more than $11,000, and our earnings on our accumulations for the year were of the order of $1,500. The precise figures are presented in the report of the Treasurer.

With the accumulations in hand and the useful size of the yearly income in sight, the Permanent Science Fund Committee is in a position to aid worthwhile projects in a significant way for the advancement through science of human welfare.

Respectfully submitted,
JOHN W. M. BUNKER, *Chairman*

May 8, 1946

On the recommendation of the Treasurer, the Academy voted that the annual assessment for the year 1946–1947 for resident Fellows be fifteen dollars.

The annual election of officers and committees resulted as follows:

Howard M. Jones	*President*
Roland G. D. Richardson	*Vice-President for Class I*
John W. M. Bunker	*Vice-President for Class II*
Erwin N. Griswold	*Vice-President for Class III*
Donald Scott	*Vice-President for Class IV*
Lewis Don Leet	*Corresponding Secretary*
Isadore Amdur	*Recording Secretary*
Horace S. Ford	*Treasurer*
Frederick H. Pratt	*Librarian*
Taylor Starck	*Editor*

COUNCILLORS FOR FOUR YEARS

Philip Franklin	Class I
Frederick K. Morris	Class II
Charles E. Wyzanski, Jr.	Class III
John G. Beebe-Center	Class IV

COMMITTEE ON PERMANENT SCIENCE FUND

John W. M. Bunker, *Chairman*

Roger Adams	Albert B. Hastings
Kirk Bryan	Edward L. Moreland
Lee A. DuBridge	Payson S. Wild, Jr.

FINANCE COMMITTEE

Jerome C. Hunsaker	Henry P. Kendall
Ralph E. Freeman	Henry L. Shattuck

RUMFORD COMMITTEE

Harlow Shapley, *Chairman*

Percy W. Bridgman	Joseph H. Keenan
Harry M. Goodwin	Francis O. Schmitt
George R. Harrison	Edwin H. Land

C. M. WARREN COMMITTEE

Frederick G. Keyes, *Chairman*

Louis F. Fieser	Avery A. Morton
Charles A. Kraus	Walter C. Schumb
Grinnell Jones	Kenneth L. Mark

COMMITTEE OF PUBLICATION

Taylor Starck, *Chairman, ex officio*

Ernest H. Huntress.....Class I
Kenneth V. Thimann.....Class II
Thomas North Whitehead.....Class III
Kenneth J. Conant.....Class IV

COMMITTEE OF THE LIBRARY

Frederick H. Pratt, *Chairman ex officio*

Raymond C. Archibald.....Class I
Charles A. Weatherby.....Class II
Francis N. Balch.....Class III
Henry B. Washburn.....Class IV

AUDITING COMMITTEE

Donald S. Tucker Thomas H. Sanders

HOUSE COMMITTEE

Charles M. Spofford, *Chairman*
H. Addington Bruce Robert P. Bigelow
John B. Wilbur

COMMITTEE ON MEETINGS

The President
The Recording Secretary
Edgar S. Brightman Cecilia Payne-Gaposchkin
Crane Brinton Seymour E. Harris

The general subject of the communication was *The Ecological Approach to Land Use*, treated by three speakers, as follows:

Edward H. Graham: *The Ecologists' Viewpoint.*

Seymour E. Harris: *The Economists' Viewpoint.*

Edward A. Ackerman: *The Geographers' Viewpoint.*

The meeting was dissolved at 10:30 P. M.

One Thousand Three Hundred and Twelfth Meeting

OCTOBER 9, 1946.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present sixty Fellows and fourteen guests.

The records of the meeting of May 8 were read and approved.

A vote was taken on a proposed amendment to the Statutes, Chapter XI, Article 2, which had been recommended to the Academy by the Council at the annual meeting last May. The amendment called for the addition of the Committee on the Amory Prize to the Standing Committees of the Academy by insertion in Chapter XI, Article 2, of the Statutes, of the following:

The Committee on the Amory Prize, to consist of seven Fellows, who shall consider all persons eligible for this award and recommend to the President and Fellows of the Academy a suitable recipient of the award according to the terms of the gift.

The amendment was adopted unanimously.

The Rev. M. J. Ahern, S. J., representative of the Academy at the observance of the one-hundredth anniversary of the Fine Arts Section of the Royal Belgian Academy of Sciences and Letters in Brussels, July 24–27, reported to the Fellows and guests. He presented to the President, for the Academy, a medal from the Belgian Academy.

The Corresponding Secretary reported the receipt of letters accepting Fellowship from the following: Chester M. Alter, James Gilbert Baker, John Landes Barnes, Paul Doughty Bartlett, George Wells Beadle, Roland Frank Beers, Brand Blanshard, Clarence Saunders Brigham, Theodore Henry Brown, Harvey Hollister Bundy, Subrahmanyan Chandrasekhar, Ralph Erskine Cleland, George Raleigh Coffman, John Sloan Dickey, Lee Alvin Du Bridge, David Frank Edwards, Howard Wilson Emmons, John Franklin Enders, Cornelius Searle Hurlbut, Jr., Charles Alderson Janeway, Otto Eduard Neugebauer, James Lee Peters, Kenneth David Roeder, Huntley Nowell Spaulding, Stanley Smith Stevens, Robert Burgess Stewart, Walter Hugo Stockmayer, Harold Walter Stoke, Julius Adams Stratton, Siegfried Josef Thannhauser, Edward Augustus Weeks, Jr., William Wilson Wurster; and of letters accepting Foreign Honorary Membership from Winston Churchill, William George Constable, Rudolf Florin, Clarence Decatur Howe, Bertil Lindblad, Jan Hendrik Oort, and Francisco Romero; also letters declining Fellowship from Paul Herman Buck and John Huston Finley, Jr.

The President announced that at the November meeting, the Academy would go into a Committee of the Whole to consider the Report of the Commission on the Present Status and Future of the Academy.

He also made preliminary announcements concerning the February conference on The Artist in American Society.

New members were introduced by sponsoring Fellows.

The following communication was presented:

William A. Jackson: *Forgeries and Facsimiles.*

One paper was presented by title: *Lower Permian Insects from Oklahoma. Part 1,* by F. M. Carpenter.

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and Thirteenth Meeting

NOVEMBER 13, 1946.—STATED MEETING

The Academy met at its House at 8:25 P. M.

The President in the Chair

There were present sixty-six Fellows and one guest.

The records of the meeting of October 9 were read and approved.

The President announced the inaugural lecture of The Arthur Dehon Little Memorial Lectureship series to be given by Sir Edward V. Appleton at the Massachusetts Institute of Technology, November 19, 1946. Members of the Academy were invited to attend.

New members were introduced by sponsoring Fellows.

It was moved that the Fellows present constitute a Committee of the Whole to consider the Report of the Commission on the Present Status and Future of the Academy. The motion was carried.

The President appointed Dean George R. Harrison chairman of the Committee of the Whole. The Recording Secretary acted as secretary of the Committee. It was pointed out by the chairman that action by the Committee of the Whole would take the form of favorable or adverse recommendation to the Council and Academy.

Kirtley F. Mather, chairman of the Commission, summarized the report and listed the following priorities which had been assigned by the Commission to its recommendations:

First—Increase in Membership (pp. 19–21 of Report)

Second—Establishment of a Committee on Nominations (pp. 21–22 of Report)

Third—The focus of attention upon the regional responsibilities of the Academy (pp. 17–19 of Report)

Fourth—Creation of the position of Executive Officer (pp. 37–38 of Report)

Fifth—Changes in publication policy (pp. 31–35 of Report)

Sixth—Acceptance of responsibility for leadership in formation of public opinion on matters of import to the body politic (pp. 14–16 of Report)

Seventh—Creation of a committee for the award of prizes or medals to outstanding younger American scholars (pp. 40–41 of Report).

The following recommendations were mentioned for future discussion without assignment of priorities:

Changes in the character of meetings of the Academy (pp. 22–28 of Report).

Additional changes in the House of the Academy (pp. 28–29 of Report).

Greater use of the Academy's House by outside organizations (pp. 30–31 of Report).

Sale of portions of the Library (pp. 35–36 of Report). (The majority of recommendations concerning the Library have already been realized as of this date.)

Support of expanded program by additional income resulting from the sale of the Library and by dues from the increased number of Fellows (pp. 38–39 of Report).

The following actions were taken by the Committee of the Whole:

1. It was moved that the Committee report favorably on the recommendation that "the number of Fellows shall not exceed 1000, of whom not more than 700 shall be residents of Massachusetts, nor shall there be more than 275 in any one Class."

In the discussion it was pointed out that the reduction of the percentage of Fellows from Massachusetts from 75 per cent to 70 per cent was intended to broaden the base of the membership, and that the primary purpose of the recommendation was to add vitalizing Fellows to the Academy membership and not to obtain additional revenue.

The motion was carried.

2. It was moved that the Committee report favorably on the recommendation calling for "the establishment of a Standing Committee on Nomination of Fellows and Foreign Honorary Members, consisting of two Fellows from each Class, not members of the Council, to be elected at the Annual Meeting for terms of two years, with the elections so arranged that one member of the Committee will be elected each year from each Class, and with the President of the Academy serving ex officio as the Chairman of the Committee."

It was moved that the original motion be amended to favor a Committee consisting of four Fellows from each Class, chosen one each from the four Sections, and that this representation be preserved when filling vacancies in the Committee. The motion to amend was lost.

In the discussion it was pointed out that the creation of a standing Committee on Nomination of Fellows and Foreign Honorary Members is not intended to replace but to supplement existing nomination procedures.

The original motion was carried.

3. It was moved that the Committee report favorably on the recommendation that the Fellows "focus atten-

tion upon the regional responsibilities of the Academy, but do not be unmindful of its national interests."

The motion was carried.

In the discussion of a suggestion for a regional study of New England, it was pointed out that outside financial support and qualified administrative personnel would be required for surveys as outlined in the Report of the Commission. It was also pointed out that since the living problems of New England have social and political implications and are therefore certain to become controversial at times, the Academy should be prepared to become involved in such controversies if it acts favorably on this suggestion of the Commission.

4. It was moved that the Committee report favorably on the recommendation calling for "the establishment of the position of Executive Officer of the Academy" whose duties are described in the Report of the Commission.

In the discussion, the type of person required for this position was described. It was pointed out that the Treasurer was of the opinion that funds would be available, chiefly as the result of the sale of the Library, to pay a salary sufficient to attract an Executive Officer of the proper qualifications.

The motion was carried.

The Committee of the Whole rose to report at 10:30 P. M. and then dissolved.

The meeting was dissolved at 10:35 P. M.

One Thousand Three Hundred and Fourteenth Meeting

DECEMBER 11, 1946.—STATED MEETING

The Academy met at its House at 8:17 P. M.

The President in the Chair.

There were present forty-nine Fellows and six guests.

The records of the meeting of November 13 were read and approved.

The President announced the appointment of John W. M. Bunker as Corresponding Secretary to succeed L. Don Leet, whose new duties outside the state have necessitated his resignation as Corresponding Secretary. Dean Bunker will serve until the next duly elected incumbent takes office.

The Corresponding Secretary reported on the actions taken by the Council at its meeting of this date.

New members were introduced by sponsoring Fellows.

The President announced that the speaker for the January meeting would be Professor Brand Blanshard of Yale University, who would speak on certain aspects of man's ability to comprehend the rapidly increasing store of human knowledge.

The President informed the members that four panel discussions had been planned for the February National Conference on the Support of the Visual Arts and that admission would be by ticket. He stated that the members would be informed shortly of the complete program for the conference, and of the method of applying for admission tickets.

The following communication was presented:

Julius A. Stratton: *Electronics in War and Peace.*

The meeting was dissolved at 9:55 P. M.

One Thousand Three Hundred and Fifteenth Meeting

JANUARY 8, 1947.—STATED MEETING

The Academy met at its House at 8:25 P. M.

The President in the Chair.

This meeting had been designated as Ladies' Night, and there were present about one hundred and twenty-five Fellows and guests.

The records of the meeting of December 11, 1946 were read and approved.

The Corresponding Secretary, on behalf of the Special Committee on Statutory and Legislative Changes, presented a motion recommending that the Academy rescind the current Standing Votes 1–4 inclusive, since they are no longer operative. The motion was carried unanimously.

A new member was introduced by a sponsoring Fellow.

The President outlined the final program for the February National Conference on the Support of the Visual Arts and reminded members to apply for tickets to the scheduled panel discussions.

The following communication was presented:

Brand Blanshard: *Can Man Expand with Expanding Knowledge.*

The meeting was dissolved at 9:40 P. M.

One Thousand Three Hundred and Sixteenth Meeting

FEBRUARY 14 and 15, 1947.—STATED MEETING

The Academy met at its House.

The President opened the meeting.

The meeting had been designated as the "Conference on the Artist in Contemporary American Society" and there were present about

one hundred and seventy Fellows and invited guests. The Conference was divided into four panel discussions, each with six scheduled speakers, as follows:

February 14:

10:00 A. M.—12:30 P. M. Panel Discussion I: *What does the buyer want from the artist?* Chairman, Charles S. Sawyer, Worcester Art Museum.

2:30—5:00 P. M. Panel Discussion II: *Can the artist supply what is wanted?* Chairman, Edward A. Weeks, The Atlantic Monthly.

February 15:

10:00 A. M.—12:30 P. M. Panel Discussion III: *The problem of marketing agencies.* Chairman, Bartlett H. Hayes, Jr., Addison Gallery.

2:00 P. M.—4:30 P. M. Panel Discussion IV: *The artist and the community: the problem of interaction.* Chairman, Howard Mumford Jones.

At 8:30 P. M. on February 14, W. G. Constable, Boston Museum of Fine Arts, delivered a public lecture entitled, *Art and Everyday Life.*

In conjunction with the Conference, an exhibition was arranged on the first floor of the Academy, to illustrate the way in which typical problems within various industries are handled by the contemporary industrial designer. The exhibition was organized by the Institute of Modern Art, Boston, and was open to the public Monday through Friday afternoons for four weeks beginning February 17.

One Thousand Three Hundred and Seventeenth Meeting

MARCH 12, 1947.—STATED MEETING

The Academy met at the Colonial Room of the Copley Plaza Hotel at 7:15 P. M.

The President in the Chair.

This meeting had been designated as the Second Annual Dinner meeting and there were present seventy-seven Fellows, seven of whom were honored guests, and five non-member honored guests.

The President introduced the honored guests.

He announced appointment of the Nominating Committee as follows:

Philip Franklin, of Class I, *chairman*
Louis C. Graton, of Class II
Abbott P. Usher, of Class III
Paul J. Sachs, of Class IV.

The Corresponding Secretary presented recommendations voted by the Council at a special meeting on March 11. The recommendations were in response to a report by the Treasurer and provided for:

1. Use of funds to the amount of $1,291, from the sale of the Library, to offset the deficit in over-all operations for the fiscal year 1946–1947.

2. Specified appropriations for the fiscal year 1947–1948 as follows:

for House expenses:	
Operating	$ 5,600
Meetings	2,500
Stenographer	2,100
for Library expenses:	
Salaries	3,000
Other	500
for Treasurer's expense	1,500
for President's expense	600
Amory Fund	500
Thomas Barbour Fund	250
Kennelly Fund	75
Permanent Science Fund	2,000
Publication Committee Fund	1,000
Rumford Fund	4,000
Warren Fund	1,000
Total	$24,625

The recommendations were approved as presented.

The Corresponding Secretary moved that the Academy approve a bill for presentation to the present session of the General Court to amend the Academy Charter. The bill would enable the Academy to determine the size of its membership and to pass regulations concerning election, discipline and expulsion of members. The motion was carried.

The Corresponding Secretary informed the members of the action of the Council to favor operation on yearly appropriations, without carry over of unexpended balances. This policy calls for advance appropriations for foreseeable expenses to the Standing Committees, which may apply to the Council for additional appropriations. He also stated that all occupants of the House of the Academy will share in the operating expense.

The Recording Secretary announced that a symposium on the Science Talent Search was planned for the April meeting.

The President reviewed recent Academy activities and urged greater participation by the

members in the affairs of the Academy. He announced the receipt of a gift of $5,000 to be known as the Barbour Fund, the income of which is available for general purposes.

The following communications were presented:

I. A. Richards: *The Language of the Specialist.*

William H. Davis: *The Art and Science of Labor Relations.*

The meeting dissolved at 10:40 P. M.

One Thousand Three Hundred and Eighteenth Meeting

APRIL 9, 1947.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present twenty-five Fellows and twenty-eight guests.

The records of the meetings of January 8, February 14 and 15, and March 12 were read and approved.

The Recording Secretary reported on the Initiating Meeting of the Inter-Society Committee on Science Foundation Legislation held in Washington on February 23. He also gave the results of a poll dated March 13, of delegates to the Inter-Society Committee, on questions of composition, policies, and program of a National Science Foundation.

Bart J. Bok, representative of the Academy at the first National Conference on UNESCO held in Philadelphia on March 24–26, reported on the results of the conference.

The Corresponding Secretary announced that the Council had started consideration of the recommendations of the Committee on Revision of the Statutes at its April meeting and planned to complete the discussion at its May meeting. He announced that the report to the Fellows would be made at the October meeting.

The general subject of the communication was the *National Science Talent Search.* The speakers were Harlow Shapley, Watson Davis, and Fletcher G. Watson.

At the conclusion of the discussion of the communication, it was moved and seconded that: "It is the sense of this meeting that the American Academy of Arts and Sciences should concern itself with the discovery, encouragement, and development of latent scientific talent in New England and especially in Massachusetts. It is therefore recommended that a Committee be formed under the auspices of the American Academy of Arts and Sciences, which will be broadly representative of all groups interested in science education at the secondary school level, and that this Committee be instructed to explore ways for encouraging our potential young scientists."

The motion was carried.

The meeting dissolved at 10:25 P. M.

One Thousand Three Hundred and Nineteenth Meeting

MAY 14, 1947.—ANNUAL MEETING

The Academy met at its House at 8:30 P. M.

The President in the Chair.

There were present forty-three Fellows and seven guests.

The records of the meeting of April 9 were read and approved.

The Corresponding Secretary read the names of the newly elected members of the Academy, as follows:

FELLOWS

CLASS I, SECTION 1

Howard Hathaway Aiken ..... Newton

CLASS I, SECTION 2

Hans Albrecht Bethe ..... Ithaca, N. Y.
Edward Uhler Condon ..... Washington, D. C.

CLASS I, SECTION 3

Paul Clifford Cross ..... Providence, R. I.
Clark Conkling Stephenson ..... Cambridge

CLASS I, SECTION 4

Charles Winters MacGregor ..... Belmont

CLASS II, SECTION 3

Arnold Gesell ..... New Haven, Conn.

CLASS II, SECTION 4

Arthur Wilburn Allen ..... Brookline
David Lawrence Belding ..... Boston
Sanford Burton Hooker ..... West Roxbury
Francis Minot Rackemann ..... Boston
James Stevens Simmons ..... Brookline
Richard Mason Smith ..... Boston
Merrill Clary Sosman ..... Chestnut Hill
Shields Warren ..... West Newton

CLASS III, SECTION 1

Mark DeWolf Howe ..... Cambridge
John Lord O'Brian ..... Washington, D. C.

CLASS III, SECTION 2

William Phillips ..... North Beverly
Sumner Welles ..... Oxon Hill, Md.

CLASS III, SECTION 3

George Pierce Baker.....Boston
Fritz Jules Roethlisberger.....Cambridge

CLASS III, SECTION 4

Thomas Dudley Cabot.....Weston
William Henry Claflin, Jr.....Belmont
Mildred McAfee Horton.....Wellesley
Ralph Lowell.....Westwood

CLASS IV, SECTION 1

Norman Burdett Nash.....Boston

CLASS IV, SECTION 2

Ruth Fulton Benedict.....New York, N. Y.
Wilbur Kitchener Jordan.....Cambridge

CLASS IV, SECTION 3

Ivor Armstrong Richards.....Cambridge
William Freeman Twaddell.....Providence, R. I.

CLASS IV, SECTION 4

Richard Burgin.....Brookline
John Dos Passos.....Provincetown
Milton Edward Lord.....Boxford
Lewis Mumford.....Amenia, N. Y.

FOREIGN HONORARY MEMBERS

CLASS I, SECTION 1

Edward Arthur Milne.....Oxford
Meghnad Saha.....Calcutta
G. A. Shajn.....Simeis, U. S. S. R.
Ivan Matveitch Vinogradoff.....Moscow

CLASS I, SECTION 2

Sir George Paget Thomson.....London

CLASS II, SECTION 1

Wen-hao Wong.....Nanking

CLASS II, SECTION 2

P. Maheshwari.....Dacca, India
Alf Erling Porsild.....Ottawa

CLASS II, SECTION 3

Augustus Daniel Imms, Tipton St. John's, Devonshire

CLASS III, SECTION 1

Paal Berg.....Oslo

CLASS IV, SECTION 1

Godfrey Hilton Thomson.....Edinburgh

CLASS IV, SECTION 3

Hamilton Alexander Rosskeen Gibb.....Oxford
Joseph Klausner.....Jerusalem

The following annual reports were read and approved:

REPORT FROM THE COUNCIL

Since the last report of the Council, there have been reported the deaths of twenty-three Fellows: Wilfred Bolster, Willa Sibert Cather, Henry Helm Clayton, Irving Fisher, Allyn Bailey Forbes, Roger Sherman Greene, Hammond Vinton Hayes, William Clifford Heilman, Edward Godfrey Huber, Carl Newell Jackson, Herbert Spencer Jennings, Willis Linn Jepson, Kirsopp Lake, Henry Lefavour, Edward Laurens Mark, Albert Davis Mead, John Anthony Miller, Curtis Hidden Page, Leo S. Rowe, William Berryman Scott, Horatio Elwin Smith, Bentley Wirt Warren, Westel Woodbury Willoughby; and of five Foreign Honorary Members: Miguel Asin y Palacios, Sir Joseph Barcroft, William Warwick Buckland, Pierre Janet, and Friedrich Paschen. Four Fellows have resigned: Howard Sylvester Ellis, Gottfried Haberler, Perry Gilbert Eddy Miller, and Harold Glenn Moulton.

Six Fellows have been classed as Emeriti: Reginald Aldworth Daly, Joseph Horace Faull, Sidney Bradshaw Fay, James Geddes, Jr., Charles Howard McIlwain, and George Edmond Russell.

One transfer has been made from Foreign Honorary Member to Fellow: William George Constable.

In May 1946, the election by the Council of thirty-five Fellows and seven Foreign Honorary Members was announced to the Academy: all except three of these accepted election.

The roll now includes 764 Fellows, 29 Fellows Emeriti and 116 Foreign Honorary Members (exclusive of those elected in 1947).

The Academy is informed that its petition introduced into the House and the Senate of Massachusetts to amend the Act which governs the number of members of the Academy will be given a hearing on May 19, 1947, at which officers of the Academy will be present.

The Council has voted that consideration of proposed amendments to the Statutes of the Academy will be the principal order of business of the stated meeting of the academy in October, 1947.

REPORT OF THE TREASURER

(Extract)

*RECEIPTS, 1946–1947

Academy, General:		
Investment Income	$18,673.06	
Less: Income to Special Funds	13,776.36	
	$4,896.70	
Assessments and Admission Fees	6,460.00	
		$11,356.70
Mabel S. Agassiz Fund:		
Investment Income		108.40
Amory Prize Committee:		
Investment Income		3,956.60
Thomas Barbour, Bequest from Estate of		5,000.00
Carnegie Corporation, for Visual Arts Conference		2,000.00

* Excluding sales of securities.

Kennelly Fund:		
Investment Income		$75.88
Life Membership Fund:		
From Eric G. Ball		200.00
Permanent Science Fund:		
Boston Safe Deposit and Trust Co., Trustee	$11,333.74	
Investment Income	1,788.60	
		13,122.34
Publications Committee:		
Investment Income	$2,710.00	
Sale of Publications	696.61	
Lake Publications	276.05	
		3,682.66
Rumford Committee:		
Investment Income	$4,139.60	
Return of Grant	30.74	
		4,170.34
Library Sale Fund:		
From Linda Hall Library Trustees		140,000.00
Special House Alterations Fund:		
Contributions and Sales		168.50
C. M. Warren Committee:		
Investment Income		997.28
Total Receipts		$184,838.70

*EXPENDITURES, 1946–1947

Academy, General:			
Library, Salaries	$2,492.00		
Books & Binding	413.14		
		$2,905.14	
General (Net)		2,773.91	
House (Net)		5,014.33	
President's Expense		224.93	
Treasurer's Expense (Net)		851.92	
Insurance	$1,157.63		
Less Unexpired Premiums	635.20	522.43	
			$12,292.66
Mabel S. Agassiz Fund:			
For Meetings			108.40
Amory Prize Committee			
Expense			76.50
Carnegie Corporation, for Visual Arts Conference			2,131.82
Permanent Science Fund:			
Grants		$8,625.00	
Expense		9.50	
			8,634.50
Publications Committee:			
General		$821.04	
Lake		12.56	
Hatch		2,690.19	
			3,523.79
Rumford Committee:			
Grants			800.00
Library Sale Fund:			
Boxes and Express			$2,109.67
Special Expense Fund (Mather Committee)			327.37
Special House Alterations Fund			15,378.55
C. M Warren Committee:			
Grants			1,000.00
Total Expenditures			$46,383.26

* Excluding purchases of securities.

REPORT OF THE RUMFORD COMMITTEE

Three research grants have been made:

To Dr. Leo L. Baranek, Cruft Laboratory, Harvard University, to assist in researches on the transfer of acoustic energy into heat energy in samples of fibrous materials, such as cotton, kapok, and Fiberglas. $400.

To Dr. O. Oldenberg, Physics Laboratory, Harvard University, to assist in the investigation of the kinetics of free hydroxyl radicals, $400.

To Dr. Willem J. Luyten of the University of Minnesota, to assist in researches on the motions and luminosities of dwarf binary stars, $250.

One application is pending. Unused remainders of grants have been returned from F. Schlesinger, C. T. Elvey, D. K. Fromm, and G. Z. Dimitroff, in the total amount of $764.98.

The balance in the Rumford Fund available on this date for the use of the Committee is nearly seventeen thousand dollars, and the Treasurer estimates the income for 1947–1948 will be $4,120.

The Committee plans to consider the advisability of making larger grants in aid of reserach than has heretofore been the custom. For several years we have limited our grants to four hundred dollars and less.

The Committee is in the process of selecting a candidate for the Rumford Medals, to be awarded at some meeting of the Academy during the year 1947–1948.

Satisfactory reports have been received from some Rumford Fund grantees. The Committee is in the embarrassed possession of a valuable diamond which has been returned by a grantee whose researches no longer require this accessory. The Council may wish to decide what officer or agency should be designated keeper of the Academy's jewels.

Respectfully submitted,

HARLOW SHAPLEY, *Chairman*

May 14, 1947

REPORT OF THE CYRUS M. WARREN COMMITTEE

The Committee had available for grants during the fiscal year 1946–1947 the sum of $1,000.00, which was appropriated at the March, 1946 meeting.

The following grants were made after consideration by the Committee of the applications submitted:

To Professor I. Amdur of the Massachusetts Institute of Technology, a grant of $300 for the purchase of

pure deuterium gas to be used in extending his research on scattering of high velocity hydrogen atoms by hydrogen molecules to systems involving all possible combinations of atoms and molecules of deuterium as well as atoms and molecules of hydrogen.

To Professor Edward R. Atkinson, University of New Hampshire, a grant of $400 to be used toward the purchase of a Heyrovsky Polarograph for use in connection with research on the action of reducing agents on diazotized amines.

To Professor Pierre Van Rysselberghe, University of Oregon, a grant of $300 to be applied on the purchase of an electric analyzer and two sets of platinum electrodes, items needed for continuation of research in the field of solutions.

A letter was received from Professor E. C. Gilbert of Oregon State College reporting on a 1940 grant from the Cyrus M. Warren Fund. The thermometer bridge purchased by the aid of a grant is functioning but there has been delay in publication of the material. Reprints will be forthcoming shortly.

A report from Professor Atkinson states that the polarograph has been in daily use and that a paper based on work with the instrument will be presented at the American Chemical Society meeting in New York in September.

Professor Amdur reports that the pure deuterium gas has been obtained and the research is still in progress. It is expected that experimental results will be available during the coming year.

Reprints have been received as follows:

Studies on Film-Forming Yeasts. Acid Production by Zygopichia and Zygohansenula by Walter J. Nickerson. Mycologia, *36*, 224–233 (1944).

On the Metabolism of Zygosaccharomyces by Walter J. Nickerson and William R. Carroll. Archives of Biochemistry, *7*, 257–271 (1945).

Respectfully submitted,
FREDERICK G. KEYES, *Chairman*

May 14, 1947

REPORT OF THE COMMITTEE OF PUBLICATION

The Committee has held only one meeting during the year, this a fairly long one; but a considerable amount of work was done by correspondence, since it seemed difficult to get all the members together more frequently. As only a few papers were submitted for publication, regular meetings were hardly needed.

The most considerable publication issued was the *Album of Dated Syriac Manuscripts* by W. H. P. Hatch. All the editorial work in this volume was done by the previous Editor of Publications. The volume was ready except for title page, binding, and cover jacket, and the final arrangements with the Harvard University Press. The Harvard University Press according to an earlier contract undertakes the marketing of the book and distributes review copies. The binding was delayed for a number of months because of shortage of materials, but the volume finally appeared early in 1947. Review copies have been distributed.

Late in 1946 Howard M. Jones, *The Literature of Virginia in the Seventeenth Century* appeared as Memoirs, Volume XIX, Part 2. This had been accepted in the year 1945–1946 and was partially in type when the incumbent editor assumed office.

One number of the Proceedings, Volume 76, No. 2, was accepted and published, a continuation of Frank M. Carpenter's study of *Permian Insects from Oklahoma*.

As a special publication the Committee accepted the account of the panel discussion on the *Ecological Approach to Land Use* held at the Academy's meeting of May 8, 1946. This had been printed in the *Journal of Soil and Water Conservation*, Volume I, No. 2 (October, 1946). Offprints were made and provided with a special cover and made available to Fellows.

Furthermore, the editor carried out the policy inaugurated last year of having planographed and distributed abstracts of the communications to the Academy. In this series was included a summary of the Report of the Conference on the Support of the Visual Arts held at the Academy's House on February 14 and 15, 1947.

No action is pending on any manuscript and nothing is in press. Pending are negotiations for the possible publication of a *Study of Massachusetts Facilities for Child Health* carried through by the American Pediatric Association. A meeting has been arranged for May 14 which will perhaps result in a proposal to be laid before the Editorial Committee.

The Publication Accounts were submitted by the Treasurer as of March 12, 1947. They show an overdraft of $2,182.90 in the Hatch Account but a credit balance of $9,902.79 in the General Account and a credit balance of $1,590.81 in the Lake Account. By Council action on March 11, 1947, these accounts have all been consolidated and $1000 appropriated for the initial publication expenditures for 1947–1948. The funds in sight are therefore ample for normal publication activities.

Respectfully submitted
TAYLOR STARCK, *Chairman*

May 14, 1947

REPORT OF THE LIBRARY COMMITTEE

We submit the following statement of account:

Appropriated	
Salaries	$2,700.00
Books, Periodicals, Binding	600.00
	$3,300.00
Expended	
Salaries	$2,492.00
Binding	164.90
Repair	111.00
Books of reference	137.24
	$2,905.14

Funds appropriated to the library have long covered several fields: first, the care and circulation of books, serials and pamphlets, represented in the salary of the Assistant Librarian; secondly, the filling and dispatch of completed publications and the reception of items exchanged or subscribed for, including their binding, again implemented by the same salary; third, the operation of the Academy's central office, subject to the needs of its officers, such as handling current announcements, roll of membership, collection of dues, telephone service, and items arising in connection with meetings and outside organizations—these also devolving upon the versatility of the Assistant Librarian. And it should not be forgotten that for many years that office has had, in the oversight of nearly 50,000 volumes, the sole assistance of the resident custodian of the building, separately supported by the building appropriation—these together constituting the library staff.

Economies effected by present changes are important, though as yet few. Periodical subscriptions have been virtually eliminated. From now on there will be bills for essential reference works, but none for binding other than of our own publications. Repair work on books, for years at a standstill, no longer threatens the treasury. But against these economies the library must for the time being shoulder one increase in expenditure—that of extra employment. During the concurrent renovation of the building and dismantling of stacks, the office has been sorely taxed to meet the world-wide renewal of demand for our publications, so long dammed up by war. The work of checking, sorting and shipping this material is arduous and requires specific skilled attention. This demand has fortunately been met by Mr. Richard Hoffman's experienced service; and such abilities will be required as long as the present organization of our exchange program continues.

A collection of about 850 volumes, the gift of founders and other early donors, awaits distribution to special libraries or appropriate depositories, with the desirability in mind of retaining certain items of special historical significance, some of which have been restored with great skill by Miss Irene Tilden. The majority of the volumes, the bequest of Governor Bowdoin, is fittingly destined for deposit in the James Bowdoin collection at Bowdoin College. We are grateful to Mrs. Anne Smith, who has always stood ready to serve in emergencies (as during Mrs. Ball's recent unfortunate wrist injury) for her interest and efficient aid in listing and arranging all of these ancient treasures.

Respectfully submitted,

FREDERICK HAVEN PRATT, *Chairman*

May 14, 1947

REPORT OF THE HOUSE COMMITTEE

At the request of the Lowell Institute Cooperative Broadcasting Council, office space of 1200 square feet has been provided on the fourth floor of the Academy House by removing the bookcases and books formerly occupying the westerly portion of this floor; the walls have been redecorated, the floor refinished and fluorescent lighting fixtures installed, making the quarters for the Council highly satisfactory. One-half of the cost of the repairs is to be paid by the Institute which also pays a reasonable amount towards maintenance. Prior to the allotment of this space the Council staff used the Reception Room on the Ground Floor.

The packing of books for shipment to the Linda Hall Library in Kansas City, as per contract, has been nearly completed. Due to the lack of storage space in Kansas City, the Academy has temporarily stored a considerable number of packed books in boxes.

During the year of 1946–1947 meetings have been held in the Academy Building as follows:

Antiques Committee, Massachusetts Federation of Women's Clubs	3
Boston Mineral Club	9
Brookline Bird Club	1
Children's Museum, Trustees	4
Greater Boston Orchestral Society	1
Institute for Religious and Social Studies	10
New England Botanical Club	8
N. E. Farm and Garden Association	9
Students' Branch, American Management Assoc.	1
Women's Travel Club	1
Total	47

There was received from these Societies and from the Lowell Institute Cooperative Broadcasting Council and the Boston Society of Natural History for use of facilities, the sum of $593.16. The total expenditures, however, for operation were as follows:

Custodian	$1,693.80	
Fuel	1,234.17	
Electricity (Light and Power)	432.80	
Elevator (Service and Repairs)	222.38	
Telephone	245.42	
Gas	17.32	
Water	51.40	
Equipment	600.36	
Upkeep	291.41	
Janitor's supplies and sundries	218.43	
Thomas H. Gately's pension	600.00	
		$5,607.49
Receipts		593.16
Total Net Expenses		$5,014.33

The appropriations for the House Committee for the year 1945–1946 were:

Operation	$3,600.00	
Additional salary to T. L. Redgate	450.00	
		$4,050.00

The House Committee recommends the adoption of revised Rules for the Use of the House as follows:

Preamble to be revised and simplified.

Section 4—Rule is modified by changing the rates charged for the use of the rooms as follows: For the use of the Assembly Room the rate is raised from $10 to $15. For the use of the Reading Room the rate is changed from $15 to $10, if no refreshments are served. If refreshments are served, $5 additional will be charged. Strike out in the second line "and the Reception Room" and also in the last line "for small groups" and insert "in special cases."

Section 5—The rules for keeping a visitors' book is stricken out as this rule has not been observed in the past.

Section 6—Substitute "House Committee" for "Assistant Librarian."

Section 7—Revise by striking out in the second line the words "introduced by fellows" and in the third line "and endorsed by the Council. Societies;" also strike out "not on the approved list should make" and in the same line "to the Assistant" and on the fifth line strike out "Librarian" and insert "House Committee should be made." Strike out the last two words "and in" and also strike out the last line.

The rules will then read as follows:

RULES FOR THE USE OF THE HOUSE

Preamble

The Council wishes to encourage the use of the Academy House for meetings of learned and cultural societies in accordance with the following rules:

Rules

1. The House of the Academy shall be available for the use of Fellows of the Academy at all reasonable hours.

2. Except as otherwise provided, the privilege of using the House of the Academy shall be enjoyed by Fellows only, who shall, however, be permitted to bring guests with them to a number not exceeding twenty.

3. Fellows introducing guests shall be responsible for any injury caused by them to the property of the Academy.

4. Fellows or organizations introduced by them may use the Committee Room on the ground floor and also the Assembly Hall and the Reading Room. For the use of the rooms on the ground floor no charges will be made. For the use of the Assembly Hall a charge of $15 will be made for each occasion; for the Reading Room there will be a charge of $10 if no refreshments are served; or $15, if there are refreshments. An additional charge of $5 will be made for each hour or fraction of an hour during which the rooms are occupied after 11 P. M. The House Committee is authorized, however, to reduce the charges in special cases.

5. Fellows, or organizations introduced by them, desiring to use either of the two large rooms for a meeting shall make application to the House Committee not less than one week in advance of the time at which the meeting is to be held.

6. The privileges of the House shall be limited to Fellows and their guests and to learned and cultural societies, approved by the House Committee. Written application to the House Committee should be made at least two weeks in advance of the proposed meeting.

Respectfully submitted,
CHARLES M. SPOFFORD, *Chairman*

May 14, 1947

REPORT OF THE COMMITTEE ON THE PERMANENT SCIENCE FUND

The Committee on the Permanent Science Fund recommended the following grants-in-aid which were approved by the Council of the American Academy of Arts and Sciences for the year 1946–1947.

October 1946

1. To C. L. Hayward, Associate Professor of Zoology, Brigham Young University, Provo, Utah; for travel and publication expense in an investigation of the Ecology of Alpine Biotic Communities in western North America, $500.

2. To Seymour E. Harris, Professor of Economics, Graduate School of Public Administration, Harvard College; for clerical assistance in extending a study of the Economic Aspects of the Release of Atomic Energy, $600.

3. To Herbert L. Eastlick, Associate Professor of Zoology, State College of Washington, Pullman, Washington; for equipment, expendable materials, and publication of a study on the Embryology of Melanoblasts in the Silkie Fowl, $350.

4. To C. C. Hoff, Assistant Professor of Zoology and Parasitology, Colorado Agricultural and Mechanical College, Fort Collins, Colorado; for studies on the Biota and Ecology of Certain Types of Montane Forests in Colorado, $200.

5. To T. H. Goodspeed, Professor of Botany and Director of the Botanical Garden, University of California, Berkeley, California; for services of an artist in Completing Preparation of a Monograph on Nicotiana, $550, contingent upon assurance that this aid will insure publication of same.

Total amount of grants-in-aid awarded October, 1946—$2,200.

April 1947

1. To I. Amdur, Associate Professor of Physical Chemistry, Massachusetts Institute of Technology, Cambridge 39, Massachusetts; for expendable materials and for assistance in continuation of an experimental study of atomic and molecular interaction potentials, $4,000.

2. To T. H. Bissonnette, Professor of Biology, Trinity College, Hartford 6, Connecticut; for continuation of a study of photoperiodism in animals, $400.

3. To C. J. Goin, Instructor in Biology, University of Florida, Gainesville, Florida; for a genetic study on certain amphibia in Jamaica, $350.

4. To H. B. Hitchcock, Associate Professor of Biology, Middlebury College, Middlebury, Vermont; for travel and expenses for a part of his study of the distribution and migration of *Myotis l. Lucifugus* and other bats, $450.

5. To H. L. Movius, Jr., Assistant Curator of Palaeolithic Archaeology, Peabody Museum, Harvard University, Cambridge 38, Massachusetts; for a study of the significance and chronology of the Old Stone Age cultures within the territories of the U. S. S. R., $1,500

Total amount of grants-in-aid awarded April, 1947—$6,700.

Total number of grants for 1946–1947—10.

Total amount of grants for 1946–1947—$8,900.

Respectfully submitted,
JOHN W. M. BUNKER, *Chairman*

May 14, 1947

REPORT OF THE AMORY PRIZE COMMITTEE

After considerable discussion of the deferred award to Dr. Laqueur it was voted to be the opinion of the present committee that the award voted to him in 1941 is now due, should be paid to him in any fashion he desires, and should be publicly announced.

Attention was given to the terms of the Amory award, considering the precise terms of this bequest, legal opinions regarding these terms, and understandings and precedents of the first Amory Prize Committee.

It was the consensus of opinion that the donor desired primarily that the awards be made for the encouragement of work of immediate therapeutic relevance but that such work being not available, work indirectly important to the treatment of disorders of the reproductive organs in human beings should be recognized. It was agreed that fundamental researches throwing light on the function of any of the reproductive organs has such importance.

It was further agreed that in case no single piece of work appeared to be of sufficiently great merit to justify awarding the entire prize to one individual, the available sum could most appropriately be divided into several lesser sums for individual awards.

It was the consensus that, other things being equal, awards to younger investigators rather than to established proponents would be within the letter of the terms of bequest and would most nearly promote the expressed purpose of the donor.

It was recognized that only work done in the preceding seven years was to be considered in assigning awards.

It was also decided that the funds should be awarded principally in the form of cash prizes, with some sort of relatively inexpensive scroll or certificate in addition. (The terms of the bequest permit this procedure.)

It was further agreed that the traveling expenses of the recipient, incurred in attendance upon a meeting of the Academy for receipt of the awards, would be paid and that they would be entertained at dinner on the evening of the said meeting.

The Secretary reported that an announcement of the awards with requests for nominations had been published throughout the world and that letters had been sent to several men in the field of genito-urology, asking for nominations.

Those nominated to date number twenty-nine. Recommendations for the next award will be made to the Council after November 10, 1947 upon which date the current Septennium terminates.

Respectfully submitted,
ROY G. HOSKINS, *Secretary*

On the recommendation of the Treasurer, the Academy voted that the annual assessment for the year 1947–1948 for Resident Fellows be continued at fifteen dollars.

The following officers and committees were elected for the coming year:

Howard M. Jones ..... *President*
Roland G. D. Richardson .... *Vice-President for Class I*
Irving W. Bailey ..... *Vice-President for Class II*
Erwin N. Griswold ..... *Vice-President for Class III*
Donald Scott ..... *Vice-President for Class IV*
John W. M. Bunker ..... *Corresponding Secretary*
Isadore Amdur ..... *Recording Secretary*
Horace S. Ford ..... *Treasurer*
Frederick H. Pratt ..... *Librarian*
Taylor Starck ..... *Editor*

COUNCILLORS FOR FOUR YEARS

Joseph H. Keenan ..... Class I
Paul C. Mangelsdorf ..... Class II
Harvey H. Bundy ..... Class III
William G. Constable ..... Class IV

COMMITTEE ON PERMANENT SCIENCE FUND

John W. M. Bunker, *Chairman*

Roger Adams	Edward L. Moreland
Kirk Bryan	Julius A. Stratton
A. Baird Hastings	Payson S. Wild, Jr.

FINANCE COMMITTEE

Ralph E. Freeman	Henry P. Kendall
Jerome C. Hunsaker	Henry L. Shattuck

RUMFORD COMMITTEE

Harlow Shapley, *Chairman*

Percy W. Bridgman	Joseph H. Keenan
Arthur C. Hardy	Edwin H. Land
George R. Harrison	Francis O. Schmitt

C. M. WARREN COMMITTEE

Frederick G. Keyes, *Chairman*

Louis F. Fieser	Kenneth L. Mark
Grinnell Jones	Avery A. Morton
Charles A. Kraus	Walter C. Schumb

AMORY PRIZE COMMITTEE

Edwin B. Wilson, *Chairman*

William B. Castle	George W. Thorn
Roy G. Hoskins	George B. Wislocki
Gregory Pincus	S. Burt Wolbach

COMMITTEE OF PUBLICATION

Taylor Starck, *Chairman, ex officio*

Ernest H. Huntress ..... Class I
Kenneth V. Thimann ..... Class II

Thomas North Whitehead.....Class III
Kenneth J. Conant.....Class IV

COMMITTEE ON THE LIBRARY

Frederick H. Pratt, *Chairman, ex officio*
Raymond C. Archibald.....Class I
Charles A. Weatherby.....Class II
Francis N. Balch.....Class III
Henry B. Washburn.....Class IV

AUDITING COMMITTEE

Donald S. Tucker — Thomas H. Sanders

HOUSE COMMITTEE

Charles M. Spofford, *Chairman*
Chester M. Alter — H. Addington Bruce
John B. Wilbur

COMMITTEE ON MEETINGS

The President
The Recording Secretary
Bart J. Bok — Arthur Clay Cope
Douglass V. Brown — Henry B. Phillips

A new member was introduced by a sponsoring Fellow.

The following communication was presented:

Edward U. Condon: *The Work of the National Bureau of Standards.*

The meeting was dissolved at 10:15 P. M.

One Thousand Three Hundred and Twentieth Meeting

OCTOBER 8, 1947.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present forty-two Fellows.

The records of the meeting of May 14 were read and approved.

The Corresponding Secretary reported the receipt of letters accepting Fellowship from 28 newly elected Fellows: Howard Hathaway Aiken, David Lawrence Belding, Ruth Fulton Benedict, Richard Burgin, Thomas Dudley Cabot, Edward Uhler Condon, Paul Clifford Cross, John Dos Passos, Arnold Gesell, Sanford Burton Hooker, Mark DeWolfe Howe, Wilbur K. Jordan, Milton Edward Lord, Ralph Lowell, Charles Winters MacGregor, Lewis Mumford, Norman Burdett Nash, John Lord O'Brian, William Phillips, Francis Minot Rackemann, Fritz Jules Roethlisberger, James Stevens Simmons, Richard Mason Smith. Merrill Clary Sosman, Clark Conkling Stephenson, William Freeman Twaddell, Shields Warren, Sumner Welles; from 10 Foreign Honorary Members: Paal Berg, Hamilton Alexander Rosskeen Gibb, Augustus Daniel Imms, P. Maheshwari, Edward Arthur Milne, Alf Erling Porsild, Meghnad N. Saha, Sir George Paget Thomson, Godfrey Hilton Thomson, Wong Wenhao; also letters declining Fellowship from three newly elected Fellows: Hans Albrecht Bethe, Mildred McAfee Horton, Ivor Armstrong Richards.

He also announced that the Council had accepted with regret the resignations of: Walter F. Dearborn, IV, 1, Walter Hunter, IV, 1, L. Don Leet, II, 1, and that an error had been made in reporting the death of Louis E. Lapicque, Foreign Honorary Member, in the Council minutes of April 22.

The Fellows approved the action of the Council calling for a gift of $250 with a suitable document of presentation to Mrs. M. F. Ball in recognition of more than twenty-five years of faithful service to the Academy.

New members were introduced by sponsoring Fellows.

The President introduced the newly appointed Executive Officer, Ralph W. Burhoe, who told the Fellows of his future plans and solicited their cooperation in helping him to vitalize the Academy along the lines recommended in the Report on the Present Status and Future of the Academy.

The principal business of the meeting was the consideration of the Report of a Special Committee on Revision of the Statutes. The President outlined the major changes which had been made in revising the Statutes, The Corresponding Secretary reported that the Council had approved the revised Statutes as circulated to the Fellows and moved that the Academy proceed to approve the revised statutes Chapter by Chapter. The following actions were taken:

a. Chapter I, approved.
b. Chapter II, approved after discussion in which it was pointed out that the revised Statutes permitted an increase in the number of Fellows to one thousand without actually requiring expansion beyond the previous limit of eight hundred members. During the discussion it was pointed out that it would be desirable to revise the nomenclature of the classes and sections in the near future.
c. Chapter III, approved.
d. Chapter IV, approved.
e. Chapter V, approved.
f. Chapter VI, approved.
g. Chapter VII, approved.

h. Chapter VIII, approved.

i. Chapter IX, approved with the substitution of "particular publications" for "special publications" at the end of Article 6. Several typographical errors were pointed out for correction. During this discussion the Fellows were urged to make greater use of the publication facilities of the Academy for presentation of original contributions. The Treasurer felt that the Academy funds were adequate to take care of considerable expansion of this portion of the Academy's publication activities.

j. Chapter X, approved.

k. Chapter XI, approved.

l. Chapter XII, approved. A motion was lost calling for substitution of "but not less than 27" for "in a meeting of not less than forty Fellows" in the last sentence of Article 5.

A motion to adopt the revised Statutes as amended was carried.

The Corresponding Secretary, as secretary of a Special Committee on Implementing the Revised Statutes, presented the following motion:

Moved: That the Statutes as amended and enacted October 8, 1947, shall become effective following the next annual election of officers in May 1948, except that:

(1) The Council, at its meeting on November 12, 1947, shall appoint an interim special Committee on Membership to serve until its successors are elected, as described in Chap. XI (Revised), Art. 1, Sec. ii, with duties as specified in Chap. III (Revised).

(2) The nomination and election of Fellows in May, 1948 shall be according to procedure as set forth in Chap. III (Revised).

(3) The election of officers and Standing Committees in May, 1948 shall conform to the revised Statutes.

(4) Chap. VII (Revised) and Chap. VIII (Revised) pertaining respectively to the Treasurer and the Librarian shall become effective immediately.

(5) Chap. IX, on the Editor and Publications, shall be put into effect after adoption of the revised Statutes.

(6) Chap. X, concerning the Council, shall become effective at once upon vote of the Council.

Mr. Shapley, chairman of the Rumford Committee, pointed out that due to the war, no Rumford premium had been awarded for four years and that it therefore might be necessary to award a premium retroactively to fulfill the conditions of the Rumford Trust calling for a biennial recommendation to the Council of a candidate for reception of the premium. During the discussion, Mr. Wyzanski pointed out that the Statutes did not call for Council approval of research grants in aid voted by the Rumford Committee.

A vote of thanks to the Special Committee on Revision of the Statutes was passed.

The meeting was dissolved at 9:50 P. M.

One Thousand Three Hundred and Twenty-first Meeting

NOVEMBER 12, 1947.—STATED MEETING

The Academy met at its House at 8:15 P. M.

The President in the Chair.

There were present forty-seven Fellows and thirty-three guests.

The records of the meeting of October 8 were read and approved.

The Corresponding Secretary reported the following actions of the Council:

1. The designation of Walter F. Dearborn, IV, 1, as Fellow Emeritus instead of acceptance of resignation as previously recorded.

2. The acceptance with regret of the resignation of Karl Sax, II, 2.

3. Authorization of the President to appoint an interim Committee on Membership to serve until the election of the regular Committee on Membership at the next annual election.

4. Authorization of a joint Committee of the American Academy of Arts and Sciences and the Boston Museum of Science which will cooperate with other groups to encourage interest in science among secondary school students.

The President invited the Fellows, on behalf of the Committee for the Arthur Dehon Little Memorial Lecture, to attend the Second Memorial Lecture on the topic, "Physics in the Contemporary World," at the Massachusetts Institute of Technology, November 25, 1947. The Lecturer, J. Robert Oppenheimer, is a Fellow of the Academy.

New members were introduced by sponsoring Fellows.

The following communications on *Problems in Evolution* were presented:

F. L. Whipple: *Some Current Trends of Thought Concerning Cosmic Evolution.*

A. S. Romer: *Advances in the Study of Organic Evolution.*

Bart J. Bok and F. L. Hisaw commented briefly on current research trends in astronomy and biology.

The meeting was dissolved at 10:20 P. M.

One Thousand Three Hundred and Twenty-second Meeting

DECEMBER 10, 1947.—STATED MEETING

The Academy met at the Georgian Room of the Statler Hotel at 7:00 P. M.

There was no scheduled business and the Corresponding Secretary acted as toastmaster in the absence of the President.

This meeting had been designated as the Third Annual Dinner Meeting and Ladies' Night. There were present, in addition to the speaker of the evening, fifty-five Fellows and their ladies.

The Corresponding Secretary briefly addressed the meeting on the traditions of the Academy in introducing the speaker of the evening, George D. Stoddard, President of the University of Illinois, whose communication was entitled: *Science Serves Two Masters.*

The meeting dissolved at 9:30 P. M.

One Thousand Three Hundred and Twenty-third Meeting

JANUARY 14, 1948.—STATED MEETING

The Academy met at its House at 8:20 P. M.

E. N. Griswold, Vice-President, in the Chair in the absence of the President.

There were present twenty-nine Fellows and six guests.

The records of the meetings of November 12 and December 10, 1947 were read and approved.

The Corresponding Secretary reported:

1. That A. W. Allen, II, 4, G. P. Baker, III, 3, and W. H. Claflin, Jr., III, 4, had accepted Fellowship and that G. A. Shajn, I, 1, had accepted Foreign Honorary Membership.

2. That the Council had designated as Fellows Emeriti: W. L. Evans, I, 3, and F. B. Talbot, II, 4.

3. That the President had appointed the following committees:

The Committee of Publication: K. B. Murdock to replace K. J. Conant.

The Committee on UNESCO: W. G. Constable, Hudson Hoagland, F. H. Taylor, P. S. Wild, Jr., and I. Amdur, chairman.

The Committee on Popular Lectures: E. N. Griswold, Ralph Lowell, and E. C. Kemble, chairman.

Interim Special Committee on Membership: Class I: J. L. Oncley, George Scatchard; Class II: C. A. Janeway, R. H. Wetmore; Class III: R. G. Caldwell, J. R. Killian, Jr.; Class IV: C. J. Ducasse, W. F. Twaddell.

4. That the Council had approved a recommendation of The Rumford Committee granting $550 to W. F. Meggers of the National Bureau of Standards.

A new member was introduced by a sponsoring Fellow.

The following communication was presented:

W. J. Cunningham: *New England Transportation and Its Relation to the New England Economy.*

Following the discussion of the communication, A. P. Usher spoke briefly on recent research trends in economics.

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and Twenty-fourth Meeting

FEBRUARY 11, 1948.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present forty-four Fellows and one hundred and thirty guests.

The records of the meeting of January 14 were read and approved.

The Corresponding Secretary stated that there were no Council actions to report.

Two new members were introduced by sponsoring Fellows.

The following communication was presented:

John von Neumann: *Electronic Methods of Computation.*

The meeting was dissolved at 9:50 P. M.

One Thousand Three Hundred and Twenty-fifth Meeting

MARCH 10, 1948.—STATED MEETING

The Academy met at its House at 8:20 P. M.

The President in the Chair.

There were present fifty-seven Fellows and one hundred and nineteen guests including A. L. von Muralt, President of the Swiss Academy of Natural Sciences.

The records of the meeting of February 11 were read and approved.

The Corresponding Secretary reported that the Council had approved appropriations totalling $19,405 for salaries, meetings and maintenance for the next fiscal year and had recommended the sum of $15.00 for the next annual assessment.

The President announced the appointment of a Nominating Committee consisting of: R. E. Freeman, III, 3, chairman; G. J. Esselen, I, 3; C. S. Keefer, II, 4; W. O. Ault, IV, 2.

Two new members were introduced by sponsoring Fellows.

The communication entitled, *Peacetime Uses of Atomic Energy* was presented by three speakers as follows:

I. *Problems of Power Development:* E. R. Gilliland, Professor of Chemical Engineering, Massachusetts Institute of Technology.

II. *Research Problems in the Physical Sciences:* C. D. Coryell, Professor of Chemistry, Massachusetts Institute of Technology.

III. *Research Problems in the Medical Sciences:* F. D. Moore, Assistant Professor of Surgery, Harvard Medical School.

The meeting was dissolved at 10:00 P. M.

One Thousand Three Hundred and Twenty-sixth Meeting

APRIL 14, 1948.—STATED MEETING

The Academy met at its House at 8:23 P. M.

The President in the Chair.

There were present twenty-three Fellows and thirty-seven guests.

The records of the meeting of March 10 were read and approved.

The Recording Secretary, in the absence of the Corresponding Secretary, read the list of grants from the Permanent Science Fund made by the Council.

A new member was introduced by a sponsoring Fellow.

The following communication was presented:

W. G. Constable: *The Painter's Workshop.*

The meeting was dissolved at 9:45 P. M.

One Thousand Three Hundred and Twenty-seventh Meeting

MAY 12, 1948.—ANNUAL MEETING

The Academy met at its House at 8:26 P. M.

The President in the Chair.

There were present fifty-three Fellows and about sixty guests.

The records of the meeting of April 14 were read and approved.

In the absence of the Chairman of the Rumford Committee, Harlow Shapley, Percy W. Bridgman introduced the Rumford medallist for 1945, Edwin H. Land. The President presented Mr. Land with a gold and silver medal in conformity with the conditions of the award.

The communications entitled *Theory and Application of Synthetic Polarizing Sheets* and *A Brief Description of the Functional Approach to One-step Photography* were presented by Mr. Land.

The Corresponding Secretary presented the following budget items which were approved by the Fellows:

$19,405 for items as presented at the March meeting; $800 appropriation for addressograph and accessories; $15 annual assessment for the year 1948–1949.

The President read the following report on deaths, resignations, and the status of the membership:

I regret to have to report the following deaths: Twenty-three Fellows and three Fellows Emeriti—Elliott Carr Cutler (II: 4), Rollins Adams Emerson (II: 2), Henry Thatcher Fowler (FE IV: 2), James Walter Goldthwait, (II: 1), Evarts Boutell Greene (IV: 2), Robert Almer Harper (II: 2), Reid Hunt (FE II: 4), Ellsworth Huntington (II: 1), Dunham Jackson (I: 1), Henry James (IV: 4), Grinnell Jones (I: 3), Charles Atwood Kofoid (II: 3), Frank Rattray Lillie (II: 3), Thomas William Lamont (III: 4), Alfred Church Lane (II: 1), Burton Edward Livingston (II: 2), William Ralph Maxon (II: 2), James Vance May (III: 4), John Bassett Moore (III: 2), James Hugh Ryan (IV: 1), William Isaac Thomas (III: 3), Edward Sampson Thurston (III: 1), Alfred North Whitehead (FE I: 1), Herbert Percy Whitlock (II: 1), Frank Clifford Whitmore (I: 3), Clark Wissler (IV: 3); Eleven Foreign Honorary Members—Frederick Orpen Bower (II: 2), Johannes N. Brönsted (I: 3), Léon Duguit (III: 1), Henri Guy (IV: 4), Godfrey Harold Hardy (I: 1), Paul Hazard (IV: 4), Gustaf Adolf Frederik Molengraaff (II: 1), Max Planck (I: 2), Rudolf Stammler (III: 1), S. Rudolph Steinmetz (III: 3), Peter Bernhardovich Struve (III: 3).

Four Fellows have resigned: Walter Samuel Hunter (IV: 1), Lewis Don Leet (II: 1), Robert P. Patterson (III: 1), Karl Sax (II: 2).

Nine Fellows have been classed as Emeriti: As of May 1, 1947—William James Cunningham (III: 3), Walter Fenno Dearborn (IV: 1), William Lloyd Evans (I: 3), George La Piana (IV: 2), Elton Mayo (III: 3), Hervey Woodburn Shimer (II: 1), Henry Bradford Washburn (IV: 1); As of May 1, 1948—Robert Bayley Osgood (II: 4), Fritz Bradley Talbot (II: 4).

In May 1947, the election by the Council of thirty-four Fellows and thirteen Foreign Honorary Members was announced to the Academy; all except three Fellows (Hans Albrecht Bethe; Mildred McAfee Horton; Ivor Armstrong Richards) and one Foreign Honorary Member (I. M. Vinogradov) accepted election.

The roll now includes 762 Fellows, 32 Fellows Emeriti, and 117 Foreign Honorary Members (exclusive of those elected in 1948).

The following annual reports were read and approved:

REPORT OF THE TREASURER

(Extract)

*Receipts, 1947–1948

Academy, General:		
Investment Income	$32,042.51	
Less: Income to Special Funds	15,276.80	
		$16,765.71
Use of Facilities		2,403.96
Assessments and Admission Fees		6,602.50
Transfer of Unexpended Appropriations		676.63
		$26,448.80
Mabel S. Agassiz Fund:		
Investment Income		108.80
Amory Prize Committee:		
Investment Income		3,987.00
Kennelly Fund:		
Investment Income		82.00
Library Sale Fund:		
From Linda Hall Library Trustees		180,000.00
Life Membership Fund:		
From Daniel L. Marsh and Sarah Wambaugh		400.00
Permanent Science Fund:		
Boston Safe Deposit and Trust Co., Trustee	$11,894.05	
Return of Grant	350.00	
Investment Income	2,975.00	
		15,219.05
Publications Committee:		
Investment Income	$2,818.00	
Sale of Publications	512.24	
Lake Publications	662.50	
		3,992.74
Rumford Committee:		
Investment Income	$4,305.00	
Return of Grant	43.77	
		4,348.77
School Science Fund:		
Boston Society of Natural History		250.00
Special House Alterations Fund:		
Fire Loss and Sales		724.00
C. M. Warren Committee:		
Investment Income		1,001.00
Total Receipts		$236,562.16

* Excluding sales of securities.

*Expenditures, 1947–1948

Academy, General:			
Salaries and Pensions		$9,067.02	
Meetings and General Administration		3,350.74	
House Maintenance		3,976.64	
President's Expense		143.80	
Treasurer's Expense		713.81	
Special Appropriations:			
Alterations	$5,071.00		
School Science Fund	250.00		
		5,321.00	
			$22,573.01
Mabel S. Agassiz Fund:			
For Meetings			108.80
Amory Prize:			
Deferred Award		$4,300.00	
Expense		157.27	
			4,457.27
Carnegie Corporation, for Visual Arts Conference			97.34
Library Sale Fund:			
Boxes, Express, Storage, etc.			3,077.46
Permanent Science Fund:			
Grants		$6,700.00	
Expense		5.39	
			6,705.39
Publications Committee:			
General		$944.75	
Lake		10.59	
			955.34
Rumford Committee:			
Grants		$1,300.00	
Medals		591.49	
Expense		160.50	
			2,051.99
School Science Fund			63.63
Special House Alterations Fund			8,040.51
C. M. Warren Committee:			
Grants			750.00
Total Expenditures			$48,880.74

REPORT OF THE RUMFORD COMMITTEE

Three grants in aid of research have been made during the year 1947–1948 as follows:

To Dr. Stefan L. Piotrowski, of Cracow, Poland, $500, to assist in the construction of a photoelectric photometer for work on eclipsing binaries in cooperation with the International Astronomical Union's Panel on Eclipsing Binaries.

To Dr. William F. Meggers, of the National Bureau of Standards, Washington, D. C., $550, to assist in spectroscopic researches at the Bureau of Standards by Professor Catalán of Madrid, Spain.

* Excluding purchases of securities.

To Dr. Francis Birch, of the Harvard Geophysical Department, $400, to assist in preparing conductivity specimens from rocks from the Alva B. Adams Tunnel.

Awards of the Rumford Premiums and Medals were made as follows: for 1945 to Edwin H. Land for his pioneer work on Polaroid and its applications; for 1947 to E. Newton Harvey of Princeton, New Jersey, for his work on animal luminescence.

The Assistant Treasurer of the American Academy reports a balance on hand on March 8, 1948, of $20,064.89.

The estimated investment income for 1948–1949 is $4,535. The total available for appropriation is $24,599.89.

Respectfully submitted,
HARLOW SHAPLEY, *Chairman*

May 12, 1948

REPORT OF THE CYRUS M. WARREN COMMITTEE

The Committee had available for grants during 1947–1948 the sum of $1000.00 which amount was voted for awards at the meeting on March 12, 1947.

The following grants were made, after consideration by the Committee, of the applications submitted:

To Doctor Charles L. Bickel of the Phillips Exeter Academy, a grant of $150.00 to provide supplies and perhaps apparatus for research problems in organic chemistry.

To Professor L. V. Coulter of Boston University, a grant of $300.00 for the construction of apparatus in connection with a study to determine the effect of molecular structure on hydrogen bond strengths.

To Professor A. E. Martell of Clark University, a grant of $300.00 to assist in the purchase of apparatus for use in an investigation involving electrical conductivity measurements of dilute non-aqueous solutions.

A letter was received from Professor Martell reporting on the purchase of apparatus and the progress of the research program, and expressing his thanks and that of Clark University to the Cyrus M. Warren Committee for the assistance.

A letter from Doctor Bickel reports on the progress of his research project. One problem has been completed and a manuscript based on the work has been accepted for publication.

Respectfully submitted,
FREDERICK G. KEYES, *Chairman*

May 12, 1948

REPORT OF THE COMMITTEE OF PUBLICATION

The Committee has held only one meeting during the year though there was some exchange of information and opinion by correspondence and orally.

No monographs or books were submitted for publication during the year.

This is the first year under the new Statutes which require the publication of a Summer and a Winter number of the Proceedings, each of which is to include certain material. As the Academy did not begin to operate under the new Statutes until the fall, the Winter number, now in press, will be distributed to members only this month. The Summer number, part of which is in type, should be ready in September. These two numbers will conclude Volume 76. Hereafter the Winter number will appear as soon as possible after the December meeting, the Summer number after the Annual meeting.

Beginning with January, 1948, five monthly numbers of the Bulletin have been issued. In the ensuing year the statutory number of eight will be published. All the work entailed by this publication has been accomplished by the Executive Officer of the Academy, Mr. Ralph Burhoe.

The manuscript of a *Study of Massachusetts Facilities for Child Health*, mentioned in the last report, has not yet been submitted.

The expenditures for 1947–1948 were only $772.46. However the cost of two numbers of the Bulletin and of the two numbers of the Proceedings will appear in the statement for 1948–1949. The new year will also see the full volume of eight Bulletins that we estimate will cost about $1,100. The expenses for the past year were therefore abnormally small. The reserve balance of $11,832 and the estimated $2,750 income from investments provide a substantial backlog to meet unforeseen expenses or increases in the printing costs. We may also count on a certain amount from sales of publications. In the past year this item was $429.07 and we may expect the sales to continue at approximately the same rate. Funds are therefore available for the publication of all acceptable manuscripts that are likely to be presented within the coming twelve months.

The Editor has discussed with the Publication Committee and the Executive Officer the advisability of soliciting manuscripts for publication. We feel that the Fellows have gotten out of the habit of thinking of the Academy when they have manuscripts for publication. We propose to call the attention of the members to the advantages of publication in the Proceedings and the Memoirs through a note in the October number of the Bulletin. We should constantly have on hand material for one full number of the Proceedings. This would not delay publication as long as it is delayed by most professional journals, some of which are two years or more in arrears. Our aim is to achieve prompt and regular issuance of the Proceedings and to cover all the fields of interest in rotation. Obviously this goal cannot be attained unless manuscripts are regularly submitted from all classes and sections of the Academy.

Respectfully submitted,
TAYLOR STARCK, *Chairman*

May 12, 1948

REPORT OF THE LIBRARY COMMITTEE

Following the sale, so skillfully organized by Mr. Metcalf, of our main holdings to the Linda Hall Library of Kansas City, the small remainder of some 650 early volumes has been disposed as follows:

The greater part—a bequest of our first President, Governor James Bowdoin—has been deposited at Bowdoin College, where much valuable Bowdoin material is already attractively housed. The Boston Athenaeum, where for many years our library had its home, is again the custodian of the great folio sets given by John Adams and bequeathed by Benjamin Franklin, respectively. Further, a number of 18th century editions of the classics given by Francis Vergnies de Bonischere, once a prominent physician of Newburyport, are now at the Essex Institute of Salem.

It is believed the above assignments are such as to afford especially appropriate settings for these permanent loans, and at the same time to render them of most use to scholars. Our reading room will still retain a few shelves of books representative of miscellaneous early donors.

Mrs. Mabel Frothingham Ball's retirement after twenty-five years as Assistant Librarian calls for more than usual notice from the Academy. Her service, not only as a trained librarian but as a general exceutive secretary, has been uniformly faithful—at times even in the face of almost mortal illness. The detailed grasp of Academy affairs, past and present, that she acquired has of late been of invaluable aid in the institution of our new executive department.

With this occasion the traditional library administration comes to an end; but it gratifying to note the perpetuation of the post of Librarian, under which a number of important functions related to income and outgo of published material are bound to call for continued attention. The retiring Librarian would express to his fellow members of the Committee his utmost gratitude for their unstinted helpfulness and generous counsel during these years of transition.

Respectfully submitted,

FREDERICK HAVEN PRATT, *Chairman*

May 12, 1948

REPORT OF THE HOUSE COMMITTEE

The use of the House by other organizations, as recommended by the Mather Commission report, has increased greatly during the year. An indication of this is shown in the increase from $205, for the previous year, to $2,404, in the present year, in re-imbursement for the use of our facilities. The Co-operative Broadcasting Council of the Lowell Institute has continued to occupy 1,200 square feet on the fourth floor, and the second and third floors of the stacks are still being occupied by the Library of the Boston Museum of Science. The organizations in addition to the Acedemy using the facilities for meetings are listed below:

	Number of Meetings
American Association of University Women	1
American Institute of Decorators	3
Antiques Committee, Massachusetts State Federation of Women's Clubs	3
Boston College Institute of Adult Education	15
Boston Mineral Club	3
Boston Society of Civil Engineers	2
Boston Teachers Union	9
Brookline Bird Club	2
Children's Museum	4
French Center of New England	15
Herbert Read Lecture (Institute of Contemporary Art, M. I. T., etc.)	1
Institute of Religious and Social Studies	6
Joyce Kilmer Post, American Legion	9
Lowell Institute Co-operative Broadcasting Council	1
New England Botanical Club	9
New England Farm and Garden Association	7
Pan American Society	3
Radcliffe Alumnae	1
Soil Conservation Society	1
Total number of meetings (of 19 societies)	95

About 7,500 persons attended meetings at the Academy held by outside organizations.

Besides the regular meetings of the Academy, there have been about 50 meetings of various committees and sub-committees of the Academy at the House.

During the year the remainder of the library books sold to the Linda Hall Library were shipped and the top three floors of the library stack wing are now essentially empty of our books. During the year a petition for use of these top three floors by an outside organization was declined on account of expense involved and the uncertainty of the Academy's own needs.

Further alterations and renovations of the House continued. The Reading Room was cleaned and painted, and new lighting was installed; the two front rooms on the first floor were converted to office space; the main portion of the first floor was altered to make it suitable for an exhibit hall; the closet room adjacent to the Reading Room was equipped with a sink to make it more useful in connection with serving refreshments and buffet style meals in the Reading Room; the former office of the Librarian was converted to a conference room.

The expenditures of the House Committee for regular operations totalled $6,772.65, as listed below:

House Maintenance	
Coal	$1,024.08
Gas	22.05
Electricity	900.74
Elevator	545.34
Water	39.00
Equipment	298.45
Supplies and Repairs	600.97

Fire Insurance	$543.60
Telephone	262.94
Caretaker	1,933.07
Pensions	600.00
Miscellaneous	2.41
Total	$6,772.65

The appropriation for the House Committee was $5,600, in addition to which there was an income of $2,403.96 for the use of facilities, making a total of $8,003.96, and leaving unexpended, $1,231.31.

For special alterations there was expended $8,040.51. Made available for this was a total of $12,477.73, consisting of the following:

Balance remaining of first appropriation for special alterations	$6,682.73
Receipts for sale of stacks	500.00
Receipts for fire loss of equipment loaned	224.00
Appropriation by Council for further alterations	5,071.00
Total	$12,477.73

This leaves $4,437.22 unexpended balance of the funds for special alterations. The Committee revised Section 4 of the Rules for the Use of the House to read as follows:

"Fellows may use the Committee Room on the third floor without charge. For the use of this room by others, the charge will be $5.00. For the use of the Assembly Hall, a charge of $15.00 will be made for each occasion; for the Reading Room, there will be a charge of $10.00 if no refreshments are served; or $15.00 if there are refreshments. An additional charge of $5.00 will be made for each hour or fraction of an hour during which the rooms are occupied after 11 P. M. The House Committee is authorized, however, to reduce the charges in special cases."

In closing I wish to pay tribute to the excellent service rendered by our Executive Officer. Mr. Burhoe, whose energy, ability and vision simplify greatly the work of the House Committee.

Respectfully submitted,

CHARLES M. SPOFFORD, *Chairman*

May 12, 1948

REPORT OF THE COMMITTEE ON THE PERMANENT SCIENCE FUND

The Committee on the Permanent Science Fund awarded eight grants-in-aid for a total of $4,400. during the fiscal year 1947–1948, as follows:

1. To Elso S. Barghoorn, Assistant Professor of Botany and Curator of Paleobotany, Harvard University, Cambridge 38, Mass.; for a paleobotanical study of lignite in Vermont, $600.

2. To Charles T. Brues, Professor of Entomology, Emeritus, Biological Laboratories, Harvard University, Divinity Avenue, Cambridge 39, Mass., for further classification of insects in amber, $615.

3. To Lincoln Constance, University of California, Visiting Professor at Harvard University, Acting Director of Gray Herbarium, Cambridge 38, Mass.; for travel for field study in Texas on the mode of origin of certain wild plant species, $350.

4. To Kenneth J. Conant, School of Design, Harvard University, Cambridge 38, Mass.; for aid in a three dimensional study of a Mediaeval Monastic group which formerly existed at Cluny in Burgundy, $425.

5. To Hallam L. Movius, Jr., Peabody Museum, Harvard University, Cambridge 38, Mass.; for a supplementary grant for his study of Paleolithic Culture in the U. S. S. R., publication of which has been assured from another source, $750.

6. To Bernard F. Riess, Department of Animal Behavior, American Museum of Natural History, 135 Cushman Road, Scarsdale, New York; for aid in a study of relation of diet to susceptibility to audiogenic and stress shock, $1,000.

7. To Alexander Forbes, Harvard Medical School, 25 Shattuck Street, Boston, Mass.; for continuation of study of refractory phase in cerebral mechanism, $300.

8. To William M. Ingram, Department of Zoology, Mills College, Oakland 13, California; for completion of a study of "Fossil and Recent Cypraeidae of the Eastern Regions of the Americas," $360.

The Committee, for its own guidance, has formulated certain principles in respect to recommending grants-in-aid, as follows.

In general, it favors granting support to individuals rather than to organizations, although grants are permissible to public or private associations, societies or institutions.

Special consideration is deemed to be appropriate for projects on new frontiers of science, those which lie between or include two or more recognized fields, and to those proposed by investigators who may be on the threshold of investigational careers, or who are handicapped by lack of resources.

The Committee ordinarily does not approve grants for the purchase of non-expendable equipment of a type which can usually be expected of an institutional laboratory, but does recognize that for special purposes, regular or special equipment may be needed and approvable.

The Committee believes that the purpose of the Fund can best be served by something of the order of 10 grants per year, not exceeding $1,500 each, although it is aware of the accumulated funds which make possible support of a limited number of large projects.

Respectfully submitted,

JOHN W. M. BUNKER, *Chairman*

May 12, 1948

REPORT OF THE AMORY PRIZE COMMITTEE

The Committee on the Amory Prize met five times:

(1) May 7, 1947. A report was prepared for submission to the Council recommending the Prize to six persons, viz., Drs. Dorfman, Huggins, Kenyon,

Kochakian, Marrian, and Olive Smith. The report was rejected by the Council on the ground that the Septennium did not expire until November 10, 1947, and recommendations were not in order until after that date.

(2), (3) January 14 and 26, 1948. The Committee took up the rejected report, reread the Amory will, decided to place more emphasis on studies close to therapy, drew up a list of persons who should be considered for the prize, and parcelled out among the members those whose contributions each should investigate.

(4) February 11, 1948. The Committee members reported their findings; there was ample discussion, a list of six persons, viz., Drs. Huggins, Marrian, Waksman, Papanicolaou, Kolff and Gutman (who had the cooperation of his wife) was adopted in that order but without prejudice or preference as to relative merit; a report to the Council was prepared recommending that the prize be equally divided between these six and that certain arrangements be made as tokens of the esteem in which they were held by the Academy. The report was referred by the Council for legal advice, upon receipt of which it was recommitted to the Committee with a copy of the legal opinion.

(5) May 5, 1948. The Committee members studied and discussed the legal opinion, in which they were much disappointed, and formulated a new report recommending the same six persons for the prize and leaving to the Council the determination of the amounts of the prizes and the arrangements for distributing them. The amount available for the prizes is reported to be $23,289 less whatever may be appropriately deducted for administrative expenses.

Respectfully submitted,

May 12, 1948 EDWIN B. WILSON, *Chairman*

It was voted to send a note of appreciation to Frederick H. Pratt for his long service to the Academy as Librarian.

The annual election of officers and committees was held. The Fellows proposed by the Nominating Committee were elected to office as follows:

Howard M. Jones	*President*
Roland G. D. Richardson	*Vice-President for Class I*
Irving W. Bailey	*Vice-President for Class II*
Robert B. Stewart	*Vice-President for Class III*
Donald Scott	*Vice-President for Class IV*
John W. M. Bunker	*Secretary*
Horace S. Ford	*Treasurer*
Henry R. Viets	*Librarian*
Taylor Starck	*Editor*

COUNCILLORS TO SERVE FOUR YEARS

Isadore Amdur	*Class I*
Arlie V. Bock	*Class II*
Keyes DeW. Metcalf	*Class III*
Crane Brinton	*Class IV*

HOUSE COMMITTEE

Chester M. Alter, *Chairman*

H. Addington Bruce — John B. Wilbur

COMMITTEE ON MEMBERSHIP

The President, *Chairman, ex officio*

To serve for one year		*To serve for two years*
J. Lawrence Oncley	*Class I*	George Scatchard
Charles A. Janeway	*Class II*	Ralph H. Wetmore
Robert G. Caldwell	*Class III*	James R. Killian, Jr.
Curt J. Ducasse	*Class IV*	W. Freeman Twaddell

COMMITTEE ON MEETINGS

The President, *Chairman, ex officio*

The Secretary, *ex officio*

Bart J. Bok — Arthur Clay Cope

Douglass V. Brown — Henry B. Phillips

COMMITTEE ON FINANCE

The Treasurer, *Chairman, ex officio*

Ralph E. Freeman — Henry P. Kendall

Jerome C. Hunsaker — Henry L. Shattuck

AUDITING COMMITTEE

Thomas H. Sanders — Donald S. Tucker

COMMITTEE ON PUBLICATION

The Editor, *Chairman, ex officio*

Ernest H. Huntress — Kenneth V. Thimann

Kenneth B. Murdock — Thomas North Whitehead

PERMANENT SCIENCE FUND COMMITTEE

John W. M. Bunker, *Chairman*

Kirk Bryan — Edward L. Moreland

Gustavus J. Esselen — Julius A. Stratton

A. Baird Hastings — Payson S. Wild, Jr.

RUMFORD COMMITTEE

Harlow Shapley, *Chairman*

Percy W. Bridgman — Joseph H. Keenan

Arthur C. Hardy — Edwin H. Land

George R. Harrison — Francis O. Schmitt

C. M. WARREN COMMITTEE

Frederick G. Keyes, *Chairman*

Edwin J. Cohn — Charles A. Kraus

Louis F. Fieser — Avery A. Morton

Hudson Hoagland — Walter C. Schumb

AMORY PRIZE COMMITTEE

Edwin B. Wilson, *Chairman*

William B. Castle — George W. Thorn

Roy G. Hoskins — George B. Wislocki

Gregory Pincus — S. Burt Wolbach

New Fellows and Foreign Honorary Members were elected to the Academy as follows:

FELLOWS

CLASS I, SECTION 1

William Ted Martin	Cambridge
Hassler Whitney	Cambridge
Oscar Zariski	Cambridge

CLASS I, SECTION 2

Enrico Fermi.....Chicago, Ill.
Bruno Benedetto Rossi.....Cambridge
Julian Seymour Schwinger.....Cambridge
Victor Frederick Weisskopf.....Cambridge

CLASS I, SECTION 3

Carl Ferdinand Cori.....St. Louis, Mo.
Charles duBois Coryell..... Cambridge
Vincent du Vigneaud .....New York, N. Y.
Robert Burns Woodward.....Cambridge

CLASS I, SECTION 4

John Chipman.....Cambridge
Ivan Alexander Getting.....Cambridge
Edwin Richard Gilliland.....Cambridge
Hoyt Clarke Hottel.....Cambridge
William Henry McAdams.....Cambridge
Thomas Kilgore Sherwood.....Cambridge
Theodor von Kármán..... Pasadena, Cal.
Walter Gordon Whitman.....Cambridge

CLASS II, SECTION 1

Arthur Francis Buddington.....Princeton, N. J.
Adolph Knopf.....New Haven, Conn.
George Gaylord Simpson.....New York, N. Y.

CLASS II, SECTION 2

Edward Sears Castle.....Cambridge
William Jacob Robbins.....New York, N. Y.
William Randolph Taylor.....Ann Arbor, Mich.
Frits Warmolt Went.....Pasadena, Cal.

CLASS II, SECTION 3

Edward Adelbert Doisy.....St. Louis, Mo.
Wallace Osgood Fenn.....Rochester, N. Y.
Herbert Spencer Gasser.....New York, N. Y.
Edmund Newton Harvey.....Princeton, N. J.
Hubert Bradford Vickery.....New Haven, Conn.
George Wald.....Cambridge
Sewall Wright.....Chicago, Ill.

CLASS II, SECTION 4

Francis Gilman Blake.....New Haven, Conn.
Allan Macy Butler.....Boston
Edward Delos Churchill.....Boston
John Rock.....Boston

CLASS III, SECTION 1

Charles Allerton Coolidge.....Boston

CLASS III, SECTION 2

William Lockhart Clayton.....Washington, D. C.
Howard Eugene Wilson.....New York, N. Y.

CLASS III, SECTION 3

Richard Bissell, Jr.....Cambridge
Bishop Carleton Hunt.....Boston

CLASS III, SECTION 4

Erwin Dain Canham.....Boston
Charles Woolsey Cole.....Amherst
Robert Cutler.....Boston
Herbert John Davis.....Northampton
Dwight David Eisenhower.....New York, N. Y.
Carl Stephens Ell.....Boston
Francis Calley Gray.....Boston
Paul Gray Hoffman.....Washington, D. C.
Carl Tilden Keller.....Boston
David Eli Lilienthal.....Washington, D. C.
Alfred Pritchard Sloan, Jr.....New York, N. Y.
Henry Merritt Wriston.....Providence, R. I.

CLASS IV, SECTION 1

Rudolph Carnap.....Chicago, Ill.
Frederick May Eliot.....Boston
Arthur Edward Murphy.....Ithaca, N. Y.
Hans Reichenbach.....Los Angeles, Cal.
Alfred Tarski.....Berkeley, Cal.

CLASS IV, SECTION 2

Margaret Mead.....New York, N. Y.

CLASS IV, SECTION 3

Bernard Bloch.....New Haven, Conn.
Leonard Bloomfield.....New Haven, Conn.
Yuen Ren Chao.....Berkeley, Cal.
Berthold Louis Ullman.....Chapel Hill, N. C.

CLASS IV, SECTION 4

Bartlett Harding Hayes, Jr.....Andover
Edward Hopper.....New York, N. Y.
John Marin.....Cliffside Park, N. J.
Thomas Munro.....Cleveland, O.
Erwin Panofsky.....Princeton, N. J.
Bruce Simonds.....Hamden, Conn.
John Sloan.....New York, N. Y.

FOREIGN HONORARY MEMBERS

CLASS I, SECTION 2

Max von Laue.....Göttingen
Arnold Sommerfeld.....Munich

CLASS I, SECTION 3

Sir Robert Robinson.....Oxford
The Svedberg.....Upsala

CLASS II, SECTION 2

P. Boysen-Jensen.....Copenhagen
Birbal Sahni.....Lucknow, India

CLASS II, SECTION 3

Charles Herbert Best.....Toronto
Archibald Gowanlock Huntsman.....Toronto

CLASS III, SECTION 1

Léon Julliot de la Morandière.....Paris

CLASS III, SECTION 2

José d'Almada.....Lisbon

CLASS IV, SECTION 4

Jean-Marie Carré.....Paris
Diego Rivera.....Coyacan, Mexico
Jan Hendrik Scholte.....Amsterdam

The meeting dissolved at 10:07 P. M.

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